5-337

TM 5-337

DEPARTMENT OF THE ARMY TECHNICAL MANUAL

PAVING AND SURFACING OPERATIONS

This reprint includes all changes in effect at the time of publication - Change 1.

HEADQUARTERS, DEPARTMENT OF THE ARMY
FEBRUARY 1966

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TM 5-337
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CHANGE No. 1

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D. C., *3 July 1967*

PAVING AND SURFACING OPERATIONS

TM 5-337, 21 February 1966, is changed as follows:

Page 145, paragraph 244*a*. In line 2, "(fig. 79)" is changed to read "(fig. 82)."

Page 146, figure 79. The title, "Automatic curing machine" is changed to read "Transit mixer."

Paragraph 245. In line 1, "(fig. 80)" is changed to read "(fig. 83)."

Page 147, figure 80. The title, "Concrete saw" is changed to read "'Dumpcrete' truck."

Page 148, paragraph 250*a*. In line 2, "(fig. 81)" is changed to read "fig. 79)."

Paragraph 251. In line 1, "(fig. 82)" is changed to read "(fig. 80)."

Figure 81. The title, "Transit mixer" is changed to read "Longitudinal finisher."

Page 149, figure 82. The title, "'Dumpcrete' truck" is changed to read "Automatic curing machine."

Paragraph 253. In line 1, "(fig. 83)" is changed to read "(fig. 81)."

Page 150, figure 83. The title, "Longitudinal finisher" is changed to read "Concrete saw."

Page 196.

CHAPTER 17

MATS

Section I. INTRODUCTION

317. Designation

New criteria have been set forth to aid in the designation of various types of mats. Two general categories, light mats and medium mats, have been established.

a. Medium Mats. Medium mats must be able to withstand 200 simulated coverages of a 25,000-pound single wheel load with a tire pressure of 250 psi on a subgrade with a CBR value of 4 (airfield index of 6). These criteria must be met without the occurrence of excessive deflection under load and no more than 10 percent replacement of failed panels. Other requirements are that these mats must weigh less than 4.5 pounds per square foot of usable area and be in sections small enough to be readily erected by hand.

b. Light Mats. Light mats must meet the same criteria as medium mats except that the CBR value of the subgrade is raised to 10 (airfield index of 11) and the maximum weight is restricted to 3.0 pounds per square foot of usable area.

Note. The major difference between light and medium mats is the CBR requirement for the base and the weight per square foot. This allows units in the field to construct an airfield (or road) from the lightest possible mat upon evaluating soil conditions, thus saving valuable transport capacity for other items.

318. Types

a. The limited standard M6, M8, M8A1, and M9 mat may still be encountered in the field because of past inventories or limited new procurement. Although M6, M8, and M9 mat do not meet current performance or weight requirements (para 317), they will find wide application as expedient surfacings until replaced by new series of aluminum mat now under development.

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*This change supersedes appendix I, sections 1 and 2, TM 5-366, 10 November 1965.

b. A new series of experimental mats is designed to meet or exceed the weight and performance criteria for light or medium mat. Currently in the advance testing stake are the MX18B, MX18C, and MX19 aluminum mats. The MX18B and MX18C mats are similar in construction and application to the AM2 mat developed by the Navy.

c. Several new materials and techniques are currently being studied for possible application as expedient surfacings. A lightweight fiberglass mat with sufficient rigidity and durability to support aircraft operations is being investigated, as well as a spray technique using epoxy resin as a spray down mat.

319. Design and Evaluation

Design criteria for the use of mats usually are expressed in the form of an index of soil strength. The cone penetrometer is used by engineer personnel to determine an airfield index of trafficability index. This index is then used to assess mat requirements for various military applications such as theater of operations airfields, and heliports. A detailed discussion of design and evaluation is found in TM 5–330.

320. Definitions

For clarity, certain terms used in this chapter are defined below.

a. Run. A strip of mat equal to one panel in width and extending transversely, in a direction perpendicular to traffic, across the entire runway, taxiway, or roadway.

b. Row. A strip of mat equal to one panel length and extending longitudinally (parallel to the direction of traffic) for the entire length of the runway, taxiway, or roadway.

c. Side Joint. The connection used to interlock panels or runs of panels transversely in a direction perpendicular to traffic.

d. End Joint. The connection used to interlock panels longitudinally or in a direction parallel to traffic.

e. Antiskid Coating. An antiskid compound applied on the top surface of some mats to provide a skid-resistant surface, especially during inclement weather.

f. Replacement Panel. A special panel used as replacement after damage to a regular mat panel in the interior of a pavement.

g. Directional Panel. A special panel or device used in making junctures at horizontal curves, as from runway to taxiway.

h. Earth Anchors. A device used along the sides and ends of the runway to hold the mat in position.

i. Coverage. A coverage represents a sufficient number of passes of a wheel load in adjacent parallel wheel paths to completely cover a given lane within a pavement.

321. General Characteristics of Mats

The advantages and disadvantages of the various mats are as follows:

a. Advantages.

(1) Reduces construction time and effort.

(2) Increases the load-bearing capability of weak soils by distributing the wheel load over a wider area.

(3) Is recoverable for future use, although this becomes proportionately more difficult with use.

(4) Requires no special skills or equipment to place mat.

(5) Has low cubage to surface area ratio.

b. Disadvantages.

(1) Does not waterproof or dustproof an area. Requires an underlying membrane to waterproof the subgrade.

(2) Is slippery when wet unless treated with antiskid coating.

(3) Welding of aluminum mats requires special equipment and techniques.

(4) Requires a heavy maintenance effort.

(5) Is temporary.

Section II. JOB PLANNING AND ORGANIZATION

322. Preliminary Considerations

A detailed discussion of subgrade and base course preparation is given in TM 5–330.

a. Subgrade Evaluation. The subgrade must be evaluated to determine its CBR value or soil strength index. (CBR versus airfield index correlation curves are found in TM 5–330). Even if the subgrade meets the minimum strength requirement, it may be more economical to add a well-compacted (high CBR) base course. This reduces the strength requirement of the mat, allowing the utilization of a lighter mat.

b. Grade and Alinement Considerations. To provide maximum bearing surface and minimize bridging of mats, the grade should be maintained as closely as possible. If small depressions are not filled and compacted, the maximum capacity of the panel will be reduced. A tolerance of ¼ inch over a 12-foot distance has been used successfully, but actual specifications adopted will depend upon the skill of the grader operators. Hand raking may be necessary to remove small rocks which would impair the interconnecting of mats. In any case the subgrade should be leveled to practical limits and rolled with pneumatic-tire or steel-wheel rollers. Alinement is critical with mats, as correcting for errors will sometimes result in difficulty in connecting the next run (or row) of mats. Alinement corrections can be made to some extent by actually dragging the mat into alinement with trucks or bulldozers. No appreciable alinement changes can be realized by attempting to stretch or bend each run back into line.

c. Drainage. Grading should provide for adequate drainage of surface and rain waters away from the field area. The soil should be disturbed a minimum amount in obtaining the required grade to provide a soil of maximum bearing capacity. The use of membrane surfacings underlying the mat serves to waterproof the subgrade and act as a dust palliative. For a complete discussion of drainage considerations see TM 5–330.

323. Sequence of Placement Operations

The general sequence of operations for placing all types of mats is as follows:

a. Determining the material and manpower requirements.

b. Organizing the job and specific tasks.

c. Establishing original alinement.

d. Spotting bundles (pallets).

e. Spotting, carrying, and placing panels.

f. Locking joints, if necessary.

g. Checking alinement.

h. Stretching plank, if necessary.

i. Finishing sides and ends, if necessary.

j. Forming junctures, if necessary.

k. Anchoring, if necessary.

l. Laying hardstands and fillets (airfields).

324. Material Requirements

Material requirements are most easily determined in four steps—width determination, length determination, total panels, and additional material determinations. Equations 17–1, 17–2, and 17–3 are general and may be applied to any type of mat. Refer to sections III, IV, and V of this chapter for panel dimensions and details.

a. Width Determination. The width of the pavement in panels may be determined by the following formula:

$$N_w = \frac{W_s}{L_P} \qquad (17\text{–}1)$$

where, N_w=Width of structure in panels (rounded *up* to next higher half or whole panel, depending on type of mat)

W_s=Width of structure in feet

L_P=Length of mat panel in feet

Example: An airfield is 73.0 feet wide. MX19 mat ($L_p = 4.0$ feet) will be used. What is the number of rows of MX19 panels required?

Solution: $N_w = \frac{W_s}{L_P} = \frac{73.0}{4.0} = 18.25$ panels

Rounding up, 19 rows of MX19 panel would be required.

b. Length Determination. The number of runs, or the length in panels, may be calculated with the following formula:

$$N_L = \frac{12 \times L_s}{W_p} \qquad (17\text{-}2)$$

where, N_L=Length of structure in panels (rounded *up* to the next highest whole number

L_s=Length of structure in feet

W_p=Width of panel in inches

Example: The airfield in *a* above is 3,000 feet long. The width of the MX19 mat panel is 48.1 inches. How many MX19 panels are required per row?

Solution: $N_L = \frac{12 \times L_s}{W_p} = \frac{12 \times 3000}{48.1} =$ 748.4 or 749 panels

c. Total Panels. The total number of panels is determined by estimate. The governing factor is the number of panels in the runway, taxiways, and aprons. This figure is obtained by successive use of the following formula:

$$N_T = N_w \times N \qquad (17\text{-}3)$$

where, N_T=Total number of panels for structure

N_w=Width of structure in panels

N_L=Length of structure in panels

After calculating the total number of panels for each component structure, the totals are added together. Additional panels are necessary for such items as fillets in turns. These additional requirements may be obtained by either estimation or plotting on graph paper. Also, another factor should be added that considers waste, anchorage, and bent or otherwise unusable panels. This factor varies from 5 percent to 15 percent for used panels, depending on the type of mat being considered. Figure 113 shows a sample calculation sheet for determining airfield requirements.

d. Additional Materials. Miscellaneous anchor attachments, earth anchors, and cable may be necessary for anchorage. Dust palliative, aluminum welding equipment, and connectors for junctures are special items which may be required.

325. Job Organization

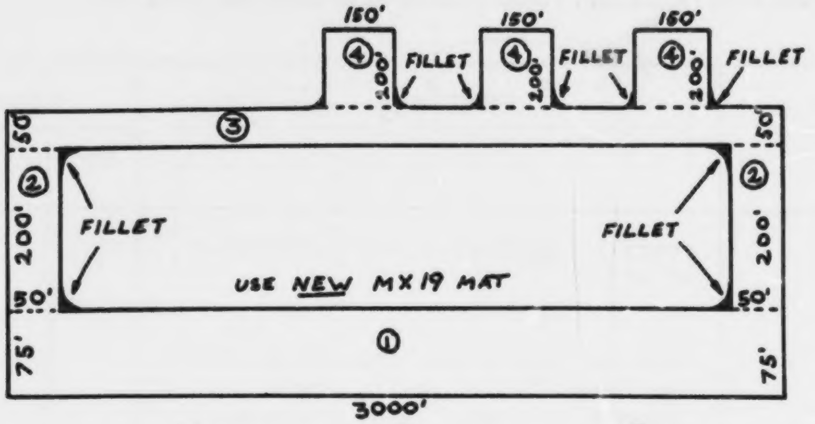
a. A typical job organization for laying MX19 mat is shown in table XVIII. This organization can be adapted to laying other types of mat with only slight variation. Depending upon the size of the job, the time available, and the numbers of men and equipment available, there are several ways a particular job can be organized. Normally, a platoon is organized into the basic work force with tactical integrity maintained by making crew assignments at the squad level. The organization must be flexible enough to adjust readily to changing situations. Should a particular phase of the project fall behind, the supervisor shifts personnel from one crew to another to obtain the most efficient balance of operations. A typical work party is composed of crews for laying out field base lines, pallet distribution and disassembly, mat placement, and anchorage installation.

b. With only one working party, normally mat placement would start at one end of the runway and proceed to the other end. If sufficient personnel are available, two working parties may start at the transverse centerline and place mat toward both ends of the runway simultaneously. After alining the mat at the center, the time required to lay the runway can be reduced approximately one-half by using two crews.

326. Pallet Deployment

a. Method. Deployment of pallets is planned so as to minimize handling and carrying of mats and the related components. Pallet deployment may be accomplished by either of the following general methods.

(1) *Forklift truck deployment.* This method of deployment may be used if a sufficient number of forklift trucks will be available to continuously supply the placement crews. Consideration must be given to the round trip distance and cycle time from the storage area to the work area when determining forklift requirements. The



①	② (2 STRIPS)	③	④ (3 STRIPS)	FILLETS
$N_W = \frac{75}{4.0} = 18.6 \cong 19$	$N_W = \frac{50}{4.0} = 12.5$	$N_W = \frac{50}{4.0} = 12.5$	$N_W = \frac{200}{4.0} = 50$	ESTIMATE 120 PANELS PER FILLET
$N_L = \frac{12 \times 3000}{48.1} = 749$	$N_L = \frac{12 \times 200}{48.1} = 50$	$N_L = \frac{12 \times 3000}{48.1} = 749$	$N_L = \frac{12 \times 150}{48.1} = 37.5$	10 × 120 = 1200 PANELS
$N_T = 19 \times 749 =$	$N_T = 12.5 \times 50 \times 2$	$N_T = 12.5 \times 749$	$N_T = 50 \times 38 \times 3$	
= 14,231 PANELS	= 1250 PANELS	= 9363 PANELS	= 5700 PANELS	

TOTAL

14,231
1,250
9,363
5,700
1,200
31,744

GRAND TOTAL
(ASSUM 10% LOSS & DAMAGE)
31,744 × 1.10 = 34,918 PANELS

Figure 113 (Superseded) *Sample calculation sheet for number of mat panels required for an airfield.*

forklift delivers the pallets directly to the mat placement crews, operating from the completed mat surface rather than the subgrade. This method has the advantage of reducing vehicle traffic on the subgrade, thus reducing the chance of damage to the membrane surfacing. Pallets are disassembled at the worksite while on the forklift trucks and the truck remains until the pallet load has been installed. Deployment of less frequently used components, such as typical keylocks, is particularly efficient using the forklift method.

(2) *On field deployment.* Where constant delivery by forklift truck is not possible, pallets may be positioned on the field along predetermined pallet rows. Delivery of pallets to the worksite should not begin until grading operations have reached a point that will permit unloading of pallets without rehandling. A lifting device, such as a mobile crane, should be available for unloading pallets from truck beds. Although, in an emergency, bundles may be dumped from dump trucks, the damage to individual panels and the membrane surface will lead to later difficulty. Pallet rows extend along the longitudinal axis of the structure, spaced so as to minimize the walking distance from pallet to mat placement point. Pallet rows may extend along the two edges of a runway as well as along the interior, depending on the width of the runway. Optimum spac-

Table XVIII (Superseded) *Typical Organization for MX19 Mat Laying Crew*

DESIGNATION	FUNCTION	PERSONNEL		
		OFF	NCO	EM
Supervisory	Overall coordination and supervision of effort.	1		
Layout Crew	Lays out base lines, transverse starting lines, fillet radii; checks alinement as installation progresses; ensures that the field access adapters are installed in correct locations; takes corrective action when necessary, to keep a uniform pattern of placement.		1	6
Pallet Crew (3 Req'd)	One pallet crew with truck assigned per pallet row; opens pallets and removes steel bands, plywood sides from site; removes skids from runway when last mat is removed from the pallet. (One crew = 4 EM)		1	12
Placement Crew	Spots each mat and maintains placement sequence; inspects joints of each mat to ensure that lock bars have been placed.		1	1
	Carry and place mats.			6
	Inserts lock bars in installed mats.			1
Anchorage Crew	Installs anchor lugs and earth anchors around perimeter of field.		1	4

ing of pallets along the pallet row may be computed by use of equation 17-4, which results in the minimum handling distance for each pallet.

$$\text{Pallet Spacing (Feet)} = \frac{(N_r)\,x\,(N_m)\,x\,(W_p)}{N_w} \qquad (17\text{-}4)$$

where,

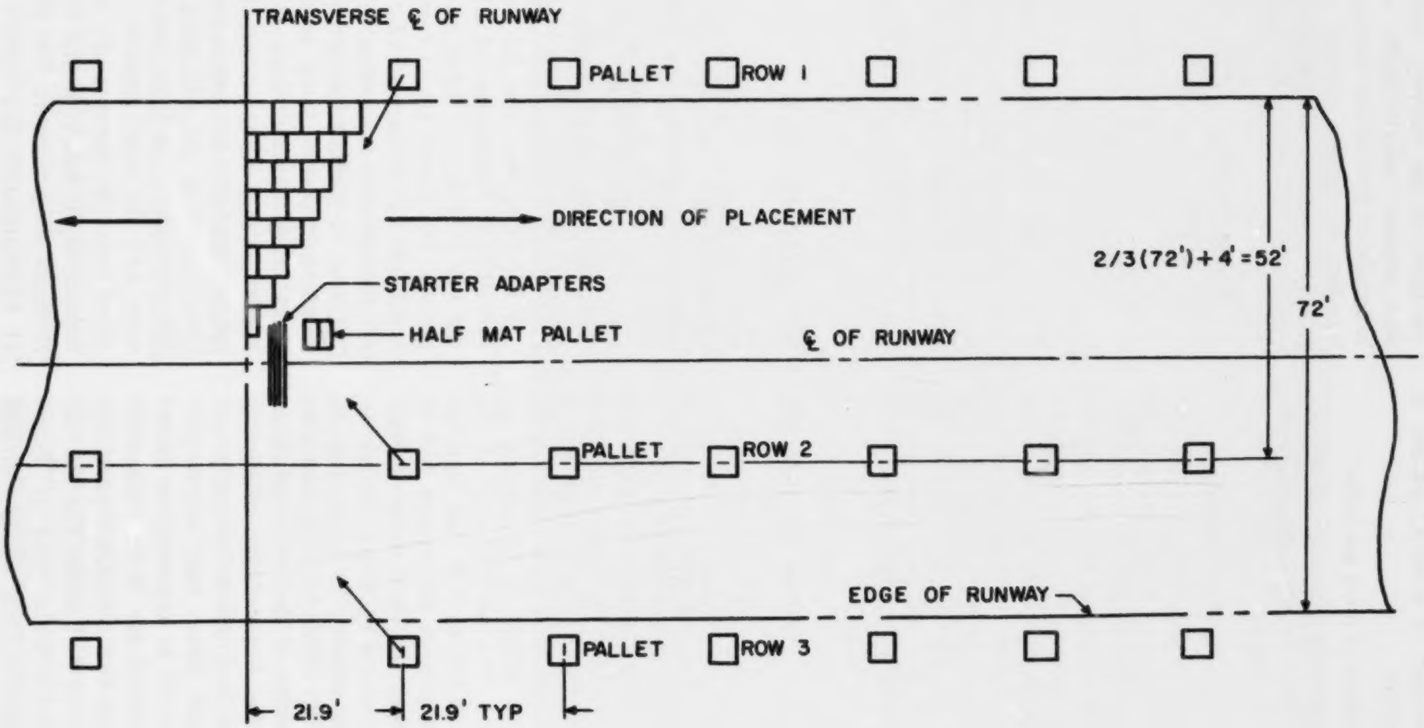

TRANSVERSE ℄ OF RUNWAY
PALLET
ROW I
DIRECTION OF PLACEMENT
2/3(72')+4'=52'
72'
STARTER ADAPTERS
HALF MAT PALLET
℄ OF RUNWAY
PALLET
ROW 2
EDGE OF RUNWAY
PALLET
ROW 3
21.9'
21.9' TYP

Figure 114 (Superseded) *Typical deployment of pallets for a 72-foot wide runway surfaced with MX19 mat.*

N_r = The number of rows of *pallets* in structure

N_m = The number of mats per pallet

W_p = Width of panel in feet (Panel dimension measured in direction parallel to traffic)

N_w = Width of structure in panels

b. Example. For a 72-foot wide runway surfaced with MX19 mat (fig. 114), three pallet rows will make a good working arrangement. One pallet row is to extend along each edge of the runway and a third row is to be located a distance of two-thirds the runway width plus the width of a panel from the edge of the runway. Thus, the second pallet row in this example will extend along a line 52 feet from the runway edge. This arrangement reduces the longest carrying distance to slightly more than one-third of the runway width. This scheme also reduces vehicle traffic on the prepared subgrade or membrane surface by limiting the number of pallets spotted on the runway interior. Spacing of pallets along the three pallet rows is computed using equation 17-4—

$$\underset{\text{(Feet)}}{\text{Pallet Spacing}} = \frac{(N_r) \times (N_m) \times (W_p)}{N_w} \qquad (17\text{-}4)$$

$$\text{Pallet Spacing} = \frac{(3) \times (32) \times (4.1\text{ ft})}{(18)} \qquad (21.9\text{ feet})$$

Place pallets on 21.9 foot centers along each pallet row, with the first pallet 21.9 feet from the end of the runway. Miscellaneous equipment pallets are deployed along the runway at intervals required for best distribution in relation to mat pallets.

Section III. M6, M8, M8A1, AND M9 MAT

327. Description

a. M6 Steel Mat. The M6 mat (fig. 115) is an improved version of the World War II PSP. Althouh this mat is no longer manufactured, a large quantity has been stockpiled and may be available. It is manufactured from rolled steel plate with three rows of punched holes to reduce the panel weight to 68 pounds for the standard panel. The nominal size of the standard panel is 10 feet by 1.25 feet, thus the unit weight is 5.4 pounds per square foot of usable area. Between the three rows of holes are two longitudinal valley ridges which increase the bridging capacity by increasing the longitudinal rigidity. (This actually increases the transverse rigidity of the connected structure.) The panel has bayonet-type connecting devices (L-shaped and pointed in only one direction) and slots along both longitudinal edges enabling the unit to be placed and joined from either side. There are 29 side connector slots along each edge of the standard panel and 14 on each side of the half panel. The M6 mat will support a single wheel load of 37,000 pounds on a subgrade CBR of 15 (airfield index of 13.5) for 700 coverages. The M6 is packaged in bundles containing six subbundles. Each subbundle contains four standard and two half panels. The material requirements are computed as discussed in paragraph 324. N_w (equation 17-1) is rounded up to the next higher half panel. Use 5 percent as a waste factor for new panels and 10 percent for recovered panels.

b. M8 Steel Mat. The M8 panel (fig. 116) is furnished in thicknesses of 0.134 inch, weighing 140 pounds, and 0.140 inch, weighing 144 pounds. The panels are 11 feet 9¾ inches long and 1 foot 7½ inches wide. In each panel there are four parallel rows of perforations, 40 holes per row, to lighten the weight. The M8 mat contains improved (over earlier designs) integral end connectors formed of metal and welded into position under the panel. These connectors, three per panel, are bent into position to lock to the adjoining panel. Bayonet side connectors are along one side of the panel only, and the edge opposite the bayonets is rolled under the bayonet slots to form a smooth contour at the subgrade and furnish additional strength along the side. The panels can be laid at approximately 361 square feet per man-hour. The M8 will support a 50,000-pound single wheel load and an 80,000-pound dual

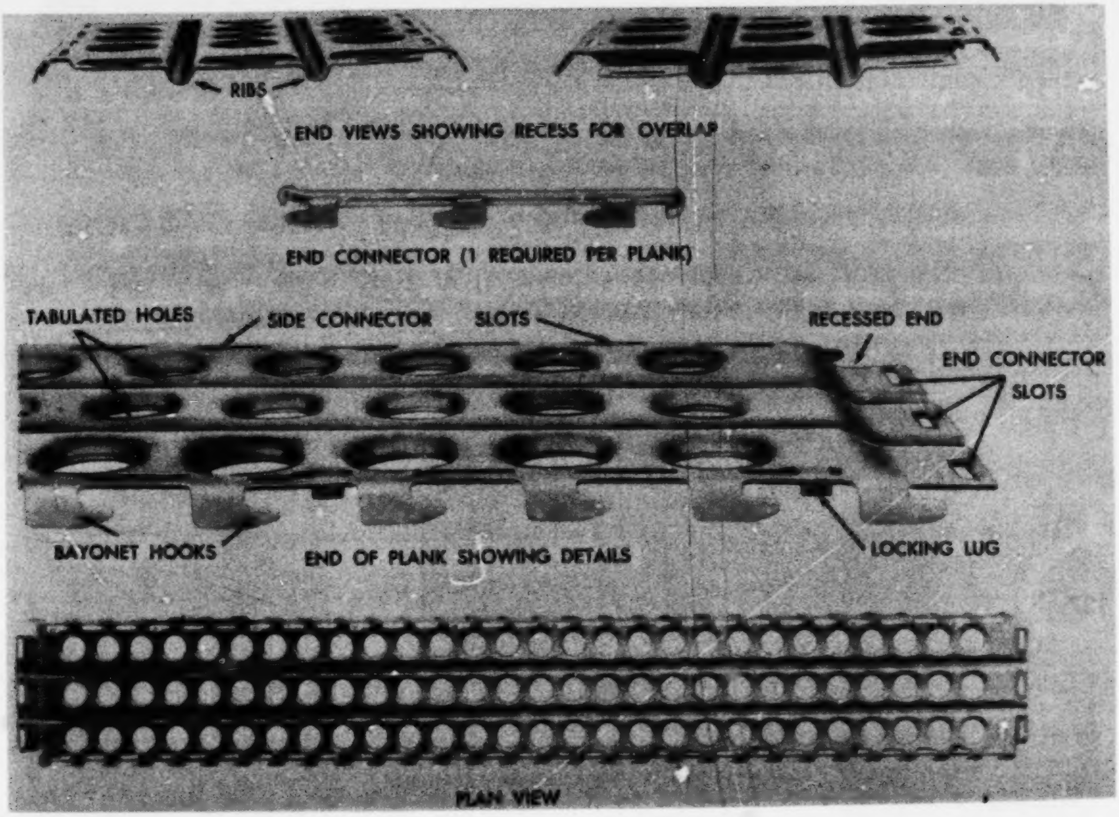

RIBS
END VIEWS SHOWING RECESS FOR OVERLAP
END CONNECTOR (1 REQUIRED PER PLANK)
TABULATED HOLES
SIDE CONNECTOR
SLOTS
RECESSED END
END CONNECTOR
SLOTS
BAYONET HOOKS
END OF PLANK SHOWING DETAILS
LOCKING LUG
PLAN VIEW

Figure 115 (Superseded) *M6 steel mat.*

wheel load on a CBR 15 (airfield index of 13.5) subgrade for 700 coverages. This is only 20 percent of the volume of traffic required of light-duty mat. The M8 is packaged in bundles containing 13 standard and 2 half panels. In computing material requirements, N_w (equation 17–1) is rounded up to the next higher half panel and a waste factor of 5 percent for new panels and 10 percent for recovered panels is used.

c. M8A1 Steel Mat. The M8A1 panels (fig. 117) are formed of 0.125-inch-thick mild-steel sheets. As shown in the figure, the panels are solid planks, with no pierced holes. The end connections incorporate moment-transferring end joints made of four ¾- by ¾- by 10½-inch sliding steel bars, driven into place with a hammer or bar. The side connectors are somewhat similar to those of the M8 with bayonets and slots. The locking lug and retainer key in the M8A1 can be bent up or down to facilitate removing and replacing. The panels are 11 feet 9¾ inches long, 1 foot 7½ inches wide, and weigh 144 pounds or 7.5 pounds per square foot. The panels can be placed at the rate of 243 square feet per man-hour. The mat qualifies as a light-duty mat on basis of performance but not on basis of weight. The M8A1 is packaged in bundles containing 13 standard and 2 half panels. Material requirements are computed the same as for the M8 mat.

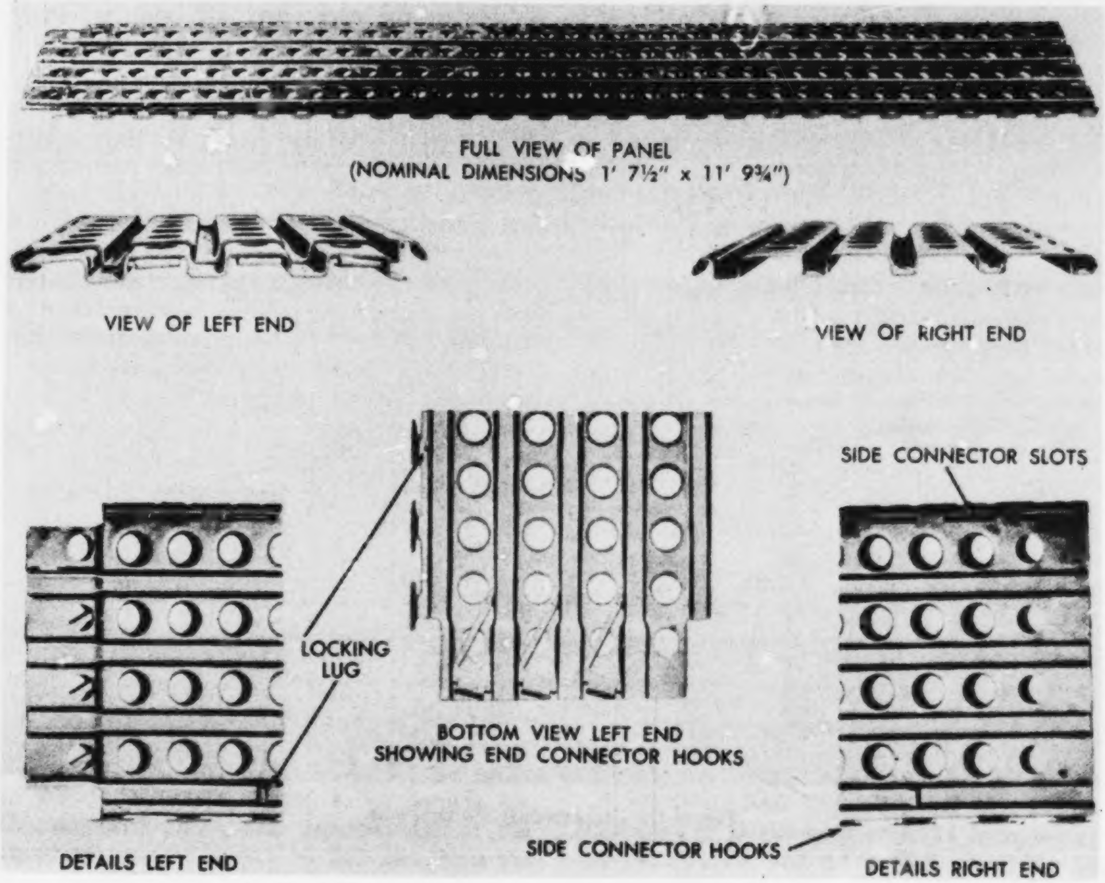

FULL VIEW OF PANEL
(NOMINAL DIMENSIONS 1' 7½" x 11' 9¾")
VIEW OF LEFT END
VIEW OF RIGHT END
SIDE CONNECTOR SLOTS
LOCKING LUG
BOTTOM VIEW LEFT END
SHOWING END CONNECTOR HOOKS
SIDE CONNECTOR HOOKS
DETAILS LEFT END
DETAILS RIGHT END

Figure 116 (Superseded) ***M8 steel mat.***

d. M9 Mat. The M9 mat is identical to the M8 in appearance except that it is made from aluminum and the panel width is increased to 22¼ (22.2) inches. The panel weight is decreased to 67 pounds and the unit weight is 3.1 pounds per square foot of usable area. The packaging method and load bearing capacity of the M8 and M9 are identical except that the design life of the M9 is only half that of the M8 mat. M9 mat can be joined to M8 mat, but not vice versa because the edge roll on the slotted side of M9 is too wide to allow M8 to lay flat once they are joined.

328. Placement

a. Placing M8, M8A1, and M9 Mat.

(1) *Locking and plank orientation.* The method of placing M8, M8A1, and M9 mat is identical except for differences in end connections. Panels can be readily placed on a crowned subgrade of up to 2 percent. The panels have both an overlap end and an underlap end. When placing panels, the underlap end must be placed on the bottom (the underlap end is the left end of

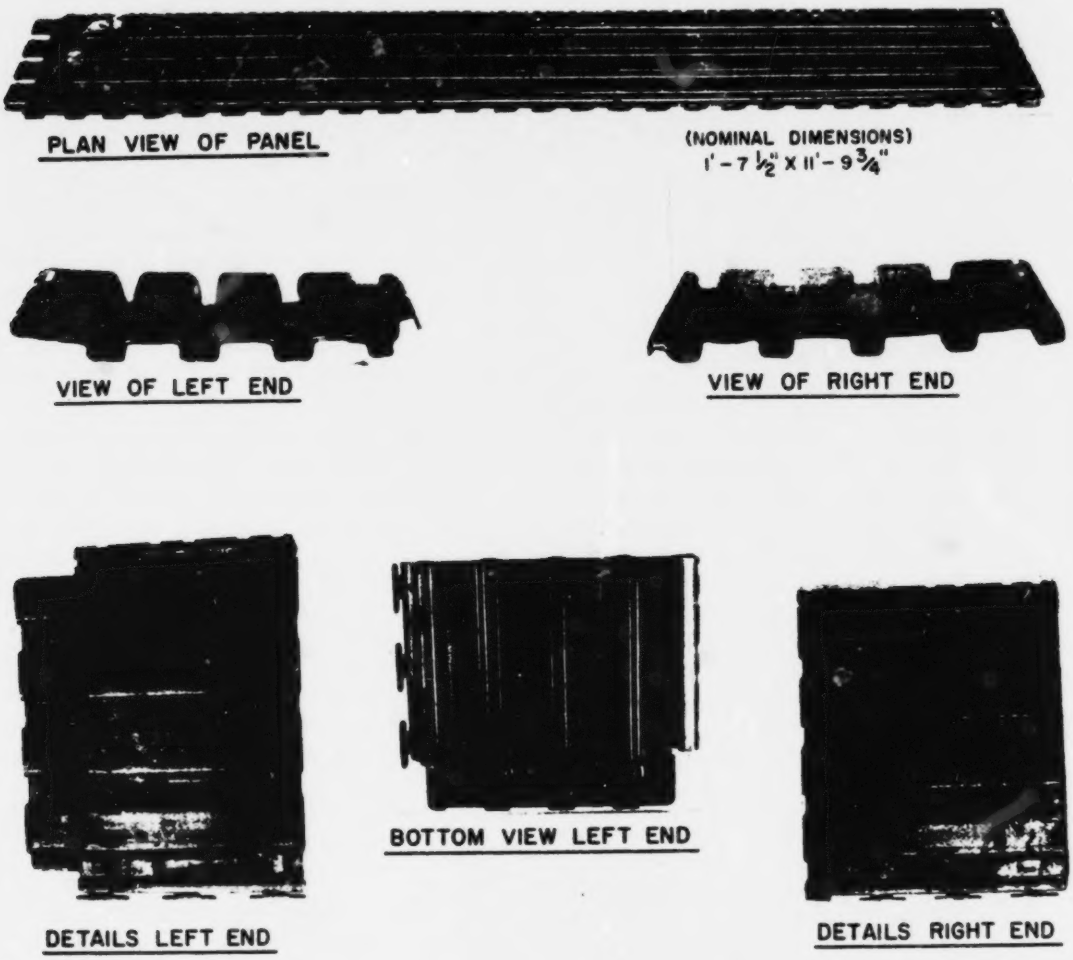

PLAN VIEW OF PANEL
(NOMINAL DIMENSIONS)
1'-7 1/2" X 11'-9 3/4"
VIEW OF LEFT END
VIEW OF RIGHT END
BOTTOM VIEW LEFT END
DETAILS LEFT END
DETAILS RIGHT END

Figure 117 (Superseded) *M8A1 steel mat.*

the top panel in fig. 116) and the overlap end is then placed on top. A reversal of the underlap and overlap positions is not possible because the underlap end ribs will not seat fully to the bottom of the overlap ribs and, if forced into place, the recessed underlap end will prohibit an even surface. When the general method of laying the panels has been established, it is readily seen that the first panel placed should be the one in the forward left-hand corner of the field (as the laying crew faces its work) with the bayonet lugs facing away from the laying crew and the slot side adjacent to them. This places the underlap end on the right and the overlap end on the left. Next, this run is completed across the strip, with the following runs starting from the left as soon as one and a half or more panels are placed in the previous run, building the mat opposite the direction faced by the laying crew as the work progresses.

(2) *Procedure for placement with one laying crew.*

(*a*) Placers start by laying one run of planks across the runway from the left side to the right side, being sure the centerline will fall at the proper place.

(*b*) A transit can be used on this and the next few runs to insure planks are laid perpendicular to the centerline.

(*c*) Pairs of placers are numbered from left to right. Plank placing team number 1 places one or two planks as required and directed; number 2 places one or more planks, etc. If the situation warrants, each team may place only one plank each. Each pair of placers thus places one, two, or more planks in each run.

(*d*) The first run is made by laying plank one; overlapping the overlap end of plank two over the underlap end of plank one by 2 inches; overlapping the overlap end of plank three over the underlap end of plank two by 2 inches, etc.

(*e*) The plank placers automatically lock the sides of the planks together when they insert the connector hooks, slide the panel to aline the locking lugs and slots, and drop the new panel into position. The end-connector man then moves the end connectors into the connector slots using a pinch bar as illustrated in figure 118. The M8A1 panels are joined by sliding the four end connector bars into the receiving slots and knocking the coverplate tab down.

Caution: **The end of the panels must be connected as they are laid because the end connectors will not fit into the connector slots if the planks are allowed to creep apart.**

(*f*) For the second and succeeding runs, the order of placement from left to right continues; however, half panels are used to start alternate runs to assure staggering of joints. Also, team number 1 will start placing the third run as soon as team number 2 places its first panel in the second run.

(*g*) Then, in turn, as in the first run, construction proceeds from left to right consecutively. This means the runway will always look like a set of stairs with placement on the left far exceeding that on the right, and team number 1 will finish work before the last team.

(*h*) Each team of two men holds the loose plank at approximately a 45° angle to the laid plank. The bayonet lugs of the loose plank are down and are engaged in the side slots of the laid planks. The tilted plank is thus slid until the bayonet lugs are securely locked in the slots and the locking lug behind the bayonet lugs is positioned in the slots. The locking lugs behind the bayonet lugs will fit into one of the two locking lug slots of the laid plank to prevent future sliding when the loose plank is lowered back to the ground in its final position.

(*i*) To make the connections lock, all panels in a run must be slid in the same direction, either left or right. Panels in alternate runs are slid in the oposite direction to maintain edge alinement and to ease removal for maintenance.

(*j*) The method of fastening end connectors is illustrated in figure 118. All connectors should be properly engaged with a pinchbar. If any of the connectors are bent out of place, they may be straightened with a sledge or claw hammer so that they can be engaged in their proper slots.

(3) *Procedure for placement with multiple crews.* If personnel are available, two crews may start at the transverse centerline and lay mat toward both

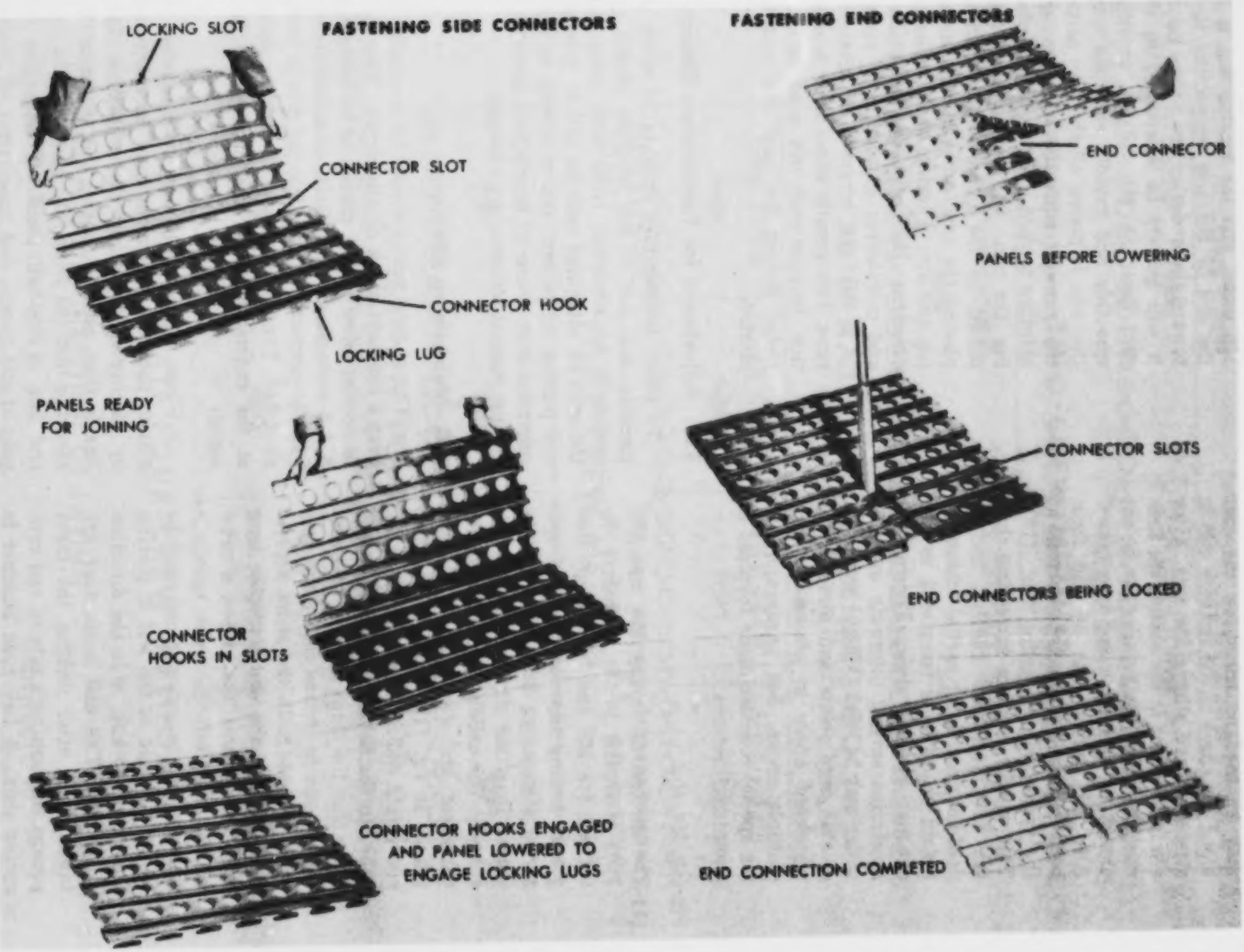

FASTENING SIDE CONNECTORS
LOCKING SLOT
CONNECTOR SLOT
CONNECTOR HOOK
LOCKING LUG
PANELS READY FOR JOINING
CONNECTOR HOOKS IN SLOTS
CONNECTOR HOOKS ENGAGED AND PANEL LOWERED TO ENGAGE LOCKING LUGS
FASTENING END CONNECTORS
END CONNECTOR
PANELS BEFORE LOWERING
CONNECTOR SLOTS
END CONNECTORS BEING LOCKED
END CONNECTION COMPLETED

Figure 118 (Superseded) ***Method of fastening M8 and M9 mat side and end connectors.***

ends of the runway simultaneously. A third crew about as large as a platoon may be used in anchoring the mat along the edges of the runway and in stretching and alining the mat. After alining the mat at the center, the time required to lay the runway can be cut almost in half by using two crews. Also the runway can be laid from both ends and a juncture formed at the transverse centerline (fig. 119). This usually requires more time than the first-mentioned method, and it does not provide for partial occupancy before the field is completed as the one-mat method does. Figure 119 illustrates several alternate methods which may be used. General principles of staggered joints and direction of placement apply to placement with multiple crews. See paragraph 333 for special considerations involved in planning junctures.

b. *Placing M6 Mat.*

(1) The method of laying M6 mat (fig 120) is similar to the procedure described for M8 and M9 except that planks having bayonet lugs and connector slots along both edges can be placed in either direction across the runway. The undelap end has a longer depressed end (left end of bottom pannel in fig. 115) than the overlap end (right end of bottom panel in fig. 115). In the field, it is simple to discover that the three pronged end connectors can be driven into place only when the end with the short depression overlaps the end with the long one. This means that when a crew places from left to right across a runway, the the underlap end must be to the right or to the left if placing from right to left, or in the direction of placing. The end connectors are fastened on after locking the three prongs through both sets of end connector slots. A ball peen hammer is the best tool for this fastening.

(2) Because the L-shaped bayonet lugs point toward the underlap end of the M6 panel, and the locking lug is in the end of the side connecting slots toward the underlap end of the panel, it will quickly be discovered in the field that the M6 will go together smoothly and rapidly only one way. One run is placed all the way across the runway with the underlap end pointing toward the direction of placing the run. The next run is then placed in the opposite direction of placing the first run with the underlap end also pointing in the opposite direction. Both direction of placing and orientation in planks or panels in a run are reversed in alternate runs. This greatly slows down production, because each run must be completed before the next one can be started.

329. Adjustment for Temperature Change

To offset temperature changes as much as possible, mat laid in any weather should occasionally be stretched from both sides and the ends by attaching vehicles and/or tractors and pulling. In general, the fit is with so little tolerance that there is insufficient protection against radical temperature changes.

330. Maintaining Alinement

a. The survey party should be available to keep a constant check on alignment. This may be accomplished with a transit or by using the 3-4-5 triangle method. Drift or misalinement must be corrected at the time the mat is being stretched. The use of temporary anchor stakes at the runway edge as the planking is laid assists in maintaining alinement.

b. When a runway has an even number of planks per run, alinement may be controlled by placing a line along the centerline. This line is then used to control the alinement by assuring that the joint falls along it. The control line is one-half panel off centerline for runs of odd panels, and one-quarter off centerline for runs with single half panels.

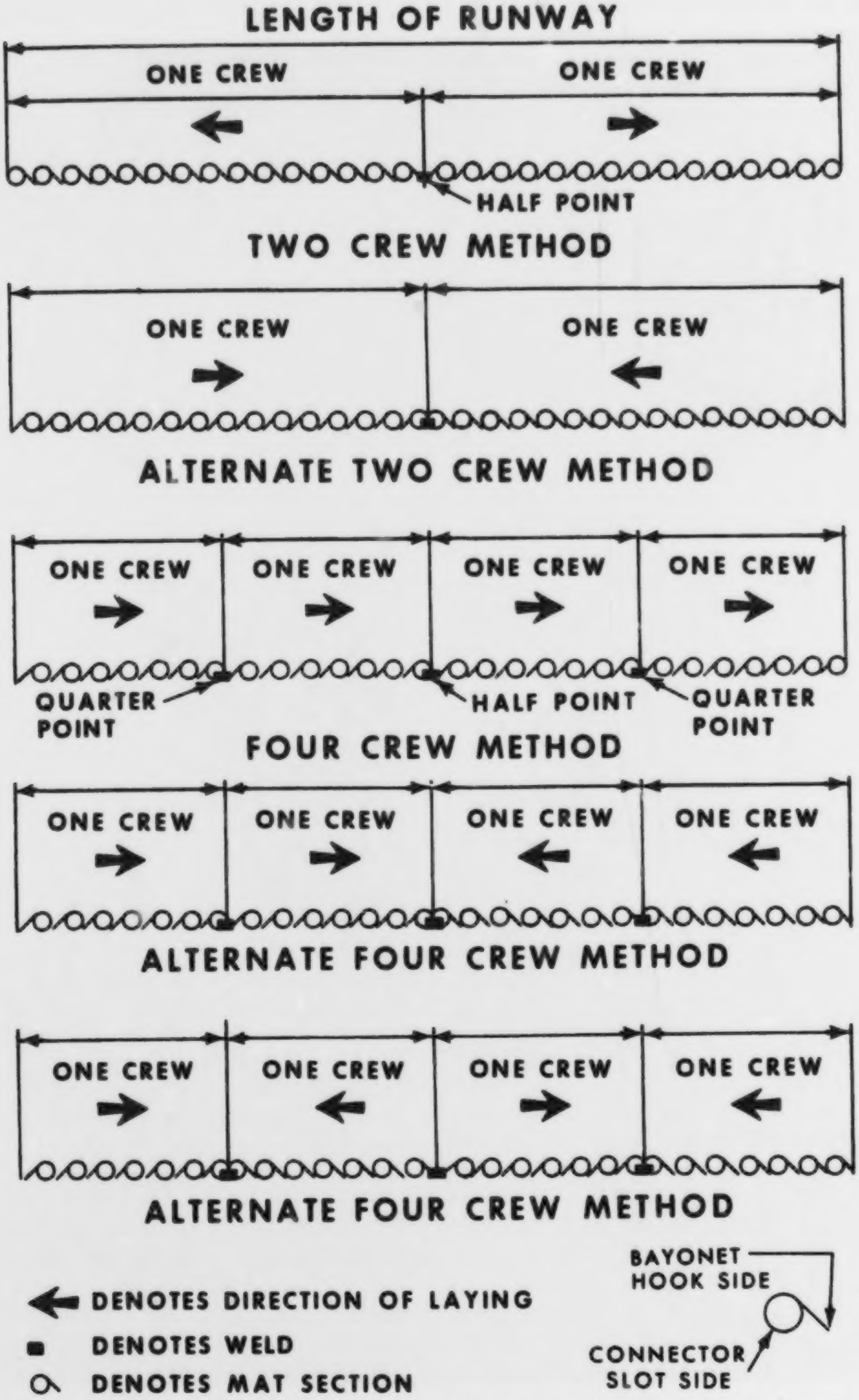

LENGTH OF RUNWAY
ONE CREW
ONE CREW
HALF POINT
TWO CREW METHOD
ONE CREW
ONE CREW
ALTERNATE TWO CREW METHOD
ONE CREW
ONE CREW
ONE CREW
ONE CREW
QUARTER POINT
HALF POINT
QUARTER POINT
FOUR CREW METHOD
ONE CREW
ONE CREW
ONE CREW
ONE CREW
ALTERNATE FOUR CREW METHOD
ONE CREW
ONE CREW
ONE CREW
ONE CREW
ALTERNATE FOUR CREW METHOD
BAYONET HOOK SIDE
DENOTES DIRECTION OF LAYING
DENOTES WELD
DENOTES MAT SECTION
CONNECTOR SLOT SIDE

Figure 119 (Superseded) *Procedure for laying M8, M8A1, or M9 mats with multiple crews.*

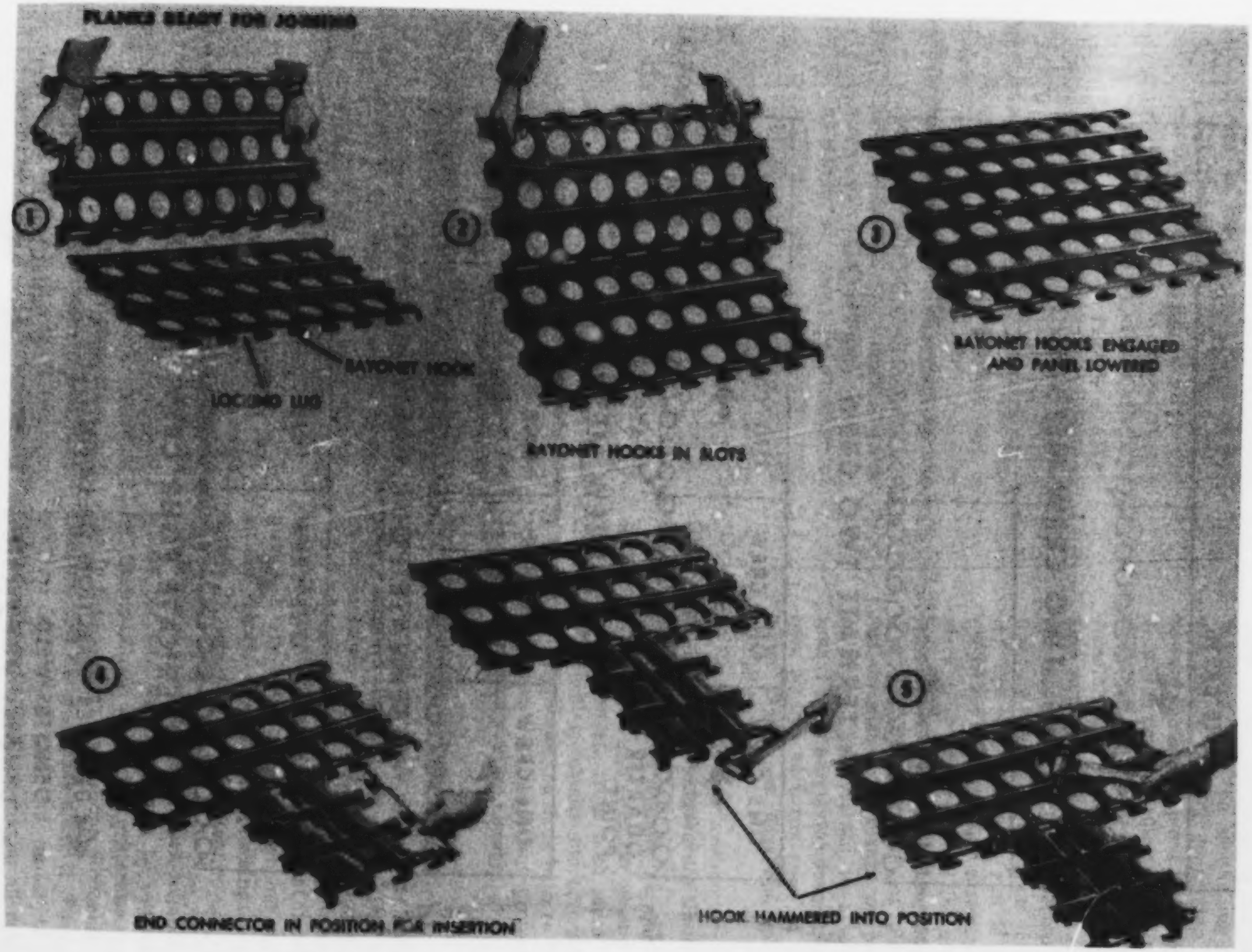

PLANKS READY FOR JOINING
①
LOCKING LUG
BAYONET HOOK
②
BAYONET HOOKS IN SLOTS
③
BAYONET HOOKS ENGAGED AND PANEL LOWERED
④
END CONNECTOR IN POSITION FOR INSERTION
⑤
HOOK HAMMERED INTO POSITION

Figure 120 (Superseded) *Method of fastening M6 mat side and end connectors.*

331. Stretching

After every 60 to 70 feet of runway has been placed, laying operations are suspended, and the section is stretched tightly by using truck winches or any other equipment available. Rebound can be prevented by driving temporary pickets or stakes through holes in the planks after each stretching operation. This stretching is necessary to maintain alinement and prevent buckling of panels.

332. Anchorage

a. Finishing Sides of Runway. To prevent curling and shifting, the planks must be anchored along the sides of the taxiway or runway. This may be done in several ways.

(1) In the most common method, the extending portions of panels are bent downward into a trench and the trench is backfilled (fig. 121). Where half planks are being used to finish the sides of the runway to an even line, using a full plank at the end of every fourth or sixth run and burying the extension is most satisfactory and involves less waste of plank and effort. The extended section is bent by a roller or truck. A cutting torch may be used to cut out a small notch in the ribs, thus greatly reducing the load required to bend the plank and controlling the point of bending.

(2) Where the whole edge, for 1- to 2-foot width, is to be bent down into a ditch, a heavy roller or wheeled vehicle may be used. If the ditch is not too deep, often a large pipe or cylinder can be rolled under the edge of the lifted landing mat, and the mat can be bent or beaten with a sledge hammer into a bend.

(3) If finished to an even edge, the mat is anchored with cables or racked wire to deadmen buried at the side. Earth anchors consisting of ¾-inch reinforcing rod, 40 inches long, may be used to anchor sides of runways or helipads. The top 6 inches of the rod should be bent over the mat.

b. Finishing Ends of Runway. A trench is excavated at each end of the runway across the entire surfaced width. The plank is continued down the slope of the trench about the width of six panels as shown in figure 121. After the plank is in place and anchored, the trench is backfilled and the fill compacted. This method of end finishing tends to reduce shifting and curling at runway ends.

333. Transitions

a. Junctures. When crews laying plank from opposite directions meet, the juncture must be welded. The welded juncture may be formed by cutting the planks with a torch and making a butt weld. It is more satisfactory to cut both planks to be welded in a rib valley, if possible. The joint can be strengthened by welding short pieces of scrap steel at intervals over the joint. M9 may be welded if aluminum welding equipment is available. An alternate method of junc-

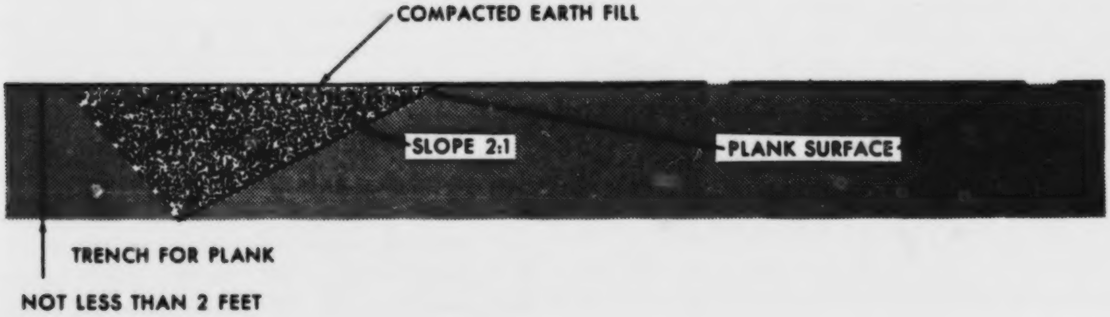


Figure 121 (Superseded) *Trench anchorage for mat at edge and end of runway.*

ture can be used with the M6 mat only; the bayonet hooks are flattened, the planks are overlapped, and a lap-weld used. This method is not satisfactory for M8, M8A1, or M9 mat because the deep ribs give an appreciable bump to such a joint.

b. Formation of Angles. The M8 method of forming angles is the recommended method where using M9 welding presents a problem. The skew panels are cut so that they butt up snugly against the straight panels, and then they are butt welded or spot welded. The cutting edge may be most easily determined by lifting up the last run of straight panels, and upon overlapping it on top of the skewed panels, its edge will act as a straightedge for marking. In the special case where plank taxiway, hardstand, or other similar surfaced areas join a concrete or asphalt surface, the last two planks are buried in the manner explained in paragraph 332 for runway ends, except that concrete or asphalt mixture is used to bury the joint.

c. Laying Hardstands and Fillets. Hardstands may be constructed by extending the landing mat in the taxiway; or a juncture may be formed by welding, and the planks placed perpendicular to the line of travel of the aircraft. In both methods, each run of plank is stopped after crossing the design edge of the fillet or hardstand so that a fillet is formed, but the edge is left stepped. The first method places the plank parallel to the line of travel, but it is satisfactory because of the small volume of travel on a hardstand. It has the advantages of ease of construction and of saving time and material. Staking down the edges of either type of hardstand generally is satisfactory. Where time permits, edges of hardstands can be buried. The forward edge of the hardstand should be buried in the same manner as the runway ends to prevent curling.

Section IV. AM2, MX18B, MX18C MAT

334. Description

a. AM2 Aluminum Mat. The AM2 is an extruded aluminum mat with a solid top and bottom as shown in figure 122. The panel is 12 feet long and 2 feet wide, requiring a placing area of 24 square feet. The panel is extruded in 6061 alloy aluminum and tempered to the T6 condition. The panels, coated with antiskid compound, weigh approximately 6.3 pounds per square foot. The connectors consist of overlap and underlap connections on the ends and hinge-joint connections on the sides. The side connectors are integral parts of the basic panel extrusions. The panels can be placed at the rate of 573 square feet per man-hour. The AM2 mat qualifies as a medium-duty mat based on performance but not on weight. The AM2 is packaged in bundles containing 11 standard-length panels, 2 half-length panels, and 13 locking bars. In computing material requirements N_w (equation 17-1) is rounded up to the nearest half panel and a waste factor of 10 percent for new panels and 15 percent for recovered panels is used.

b. MX18B and MX18C Aluminum Mat. The MX18B and MX18C aluminum mats (fig. 123) are lighter versions of the AM2 mat. The MX18B and MX18C mats meet all criteria for medium mats except weight (compare 4.7 lb per sq ft versus 4.5 lb per sq ft maximum). Both mats are identical except for a difference in aluminum alloys. They consist of extruded aluminum planks with lapped and welded end connectors. The panels are 2 feet by 12 feet and weigh approximately 113 pounds or 4.7 pounds per square foot of usable area. A half panel is also available that is 6 feet long. A short (2-ft long) locking-bar is an accessory used to complete the end connection. Both mats are packaged in bundles containing 11 standard-length and 2 half-length panels. The material requirements are computed identically to the AM2.

335. Placement

a. The general sequence for placement is to start at the transverse centerline of the runway and progress toward each end simultaneously. A special starter keylock section is laid across the centerline (fig. 124) and then individual mats are laid in a staggered-joint pattern in opposite directions from the starter keylock.

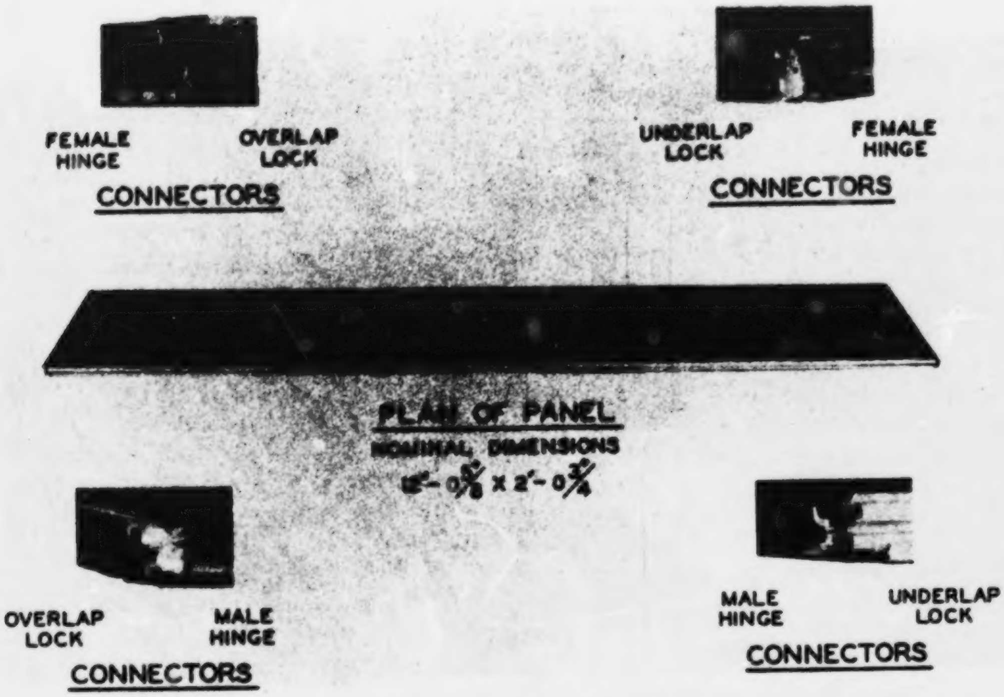

FEMALE HINGE
OVERLAP LOCK
CONNECTORS
UNDERLAP LOCK
FEMALE HINGE
CONNECTORS
PLAN OF PANEL
NOMINAL DIMENSIONS
12'-0 5/8" X 2'-0 3/4"
OVERLAP LOCK
MALE HINGE
CONNECTORS
MALE HINGE
UNDERLAP LOCK
CONNECTORS

Figure 122 (Superseded) *AM2 aluminum mat.*

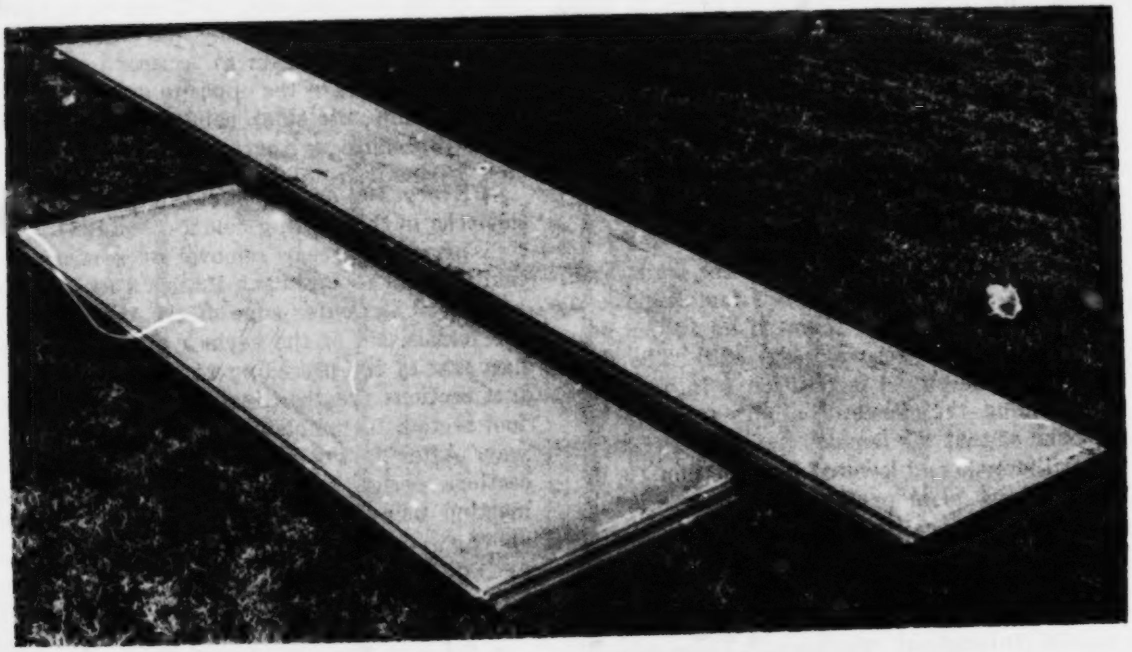


Figure 123 (Superseded) *MX18B aluminum mat.*

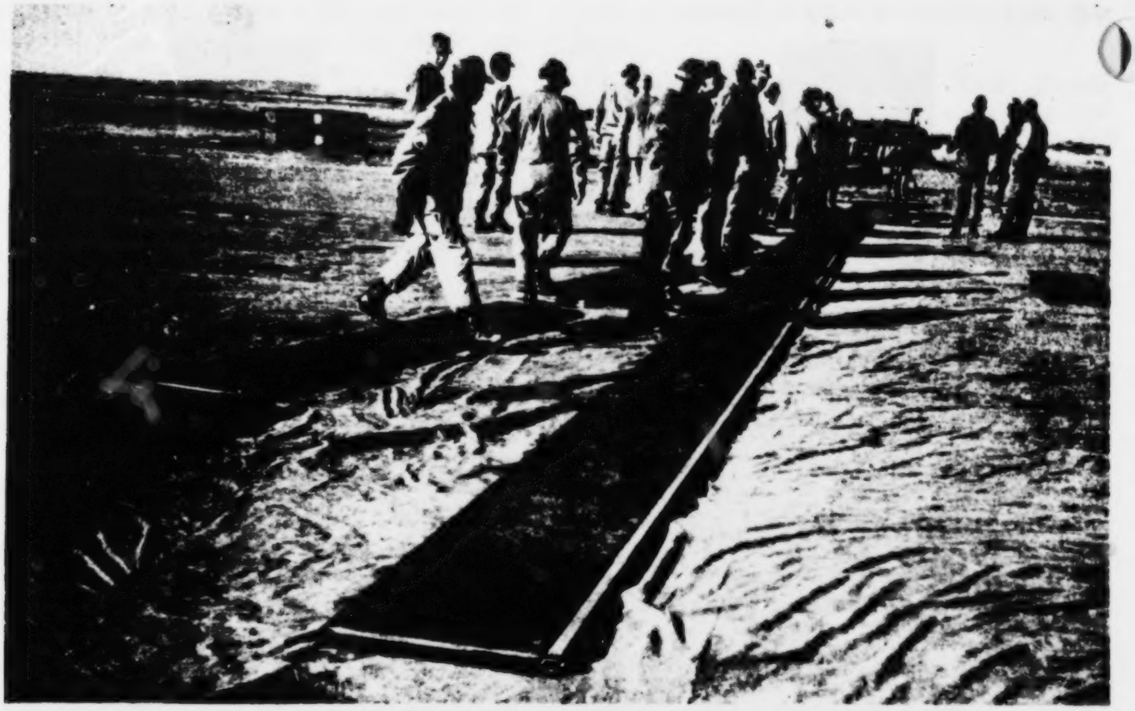


Figure 124 (Superseded) *AM2 starter keylock placed at transverse centerline of runway.*

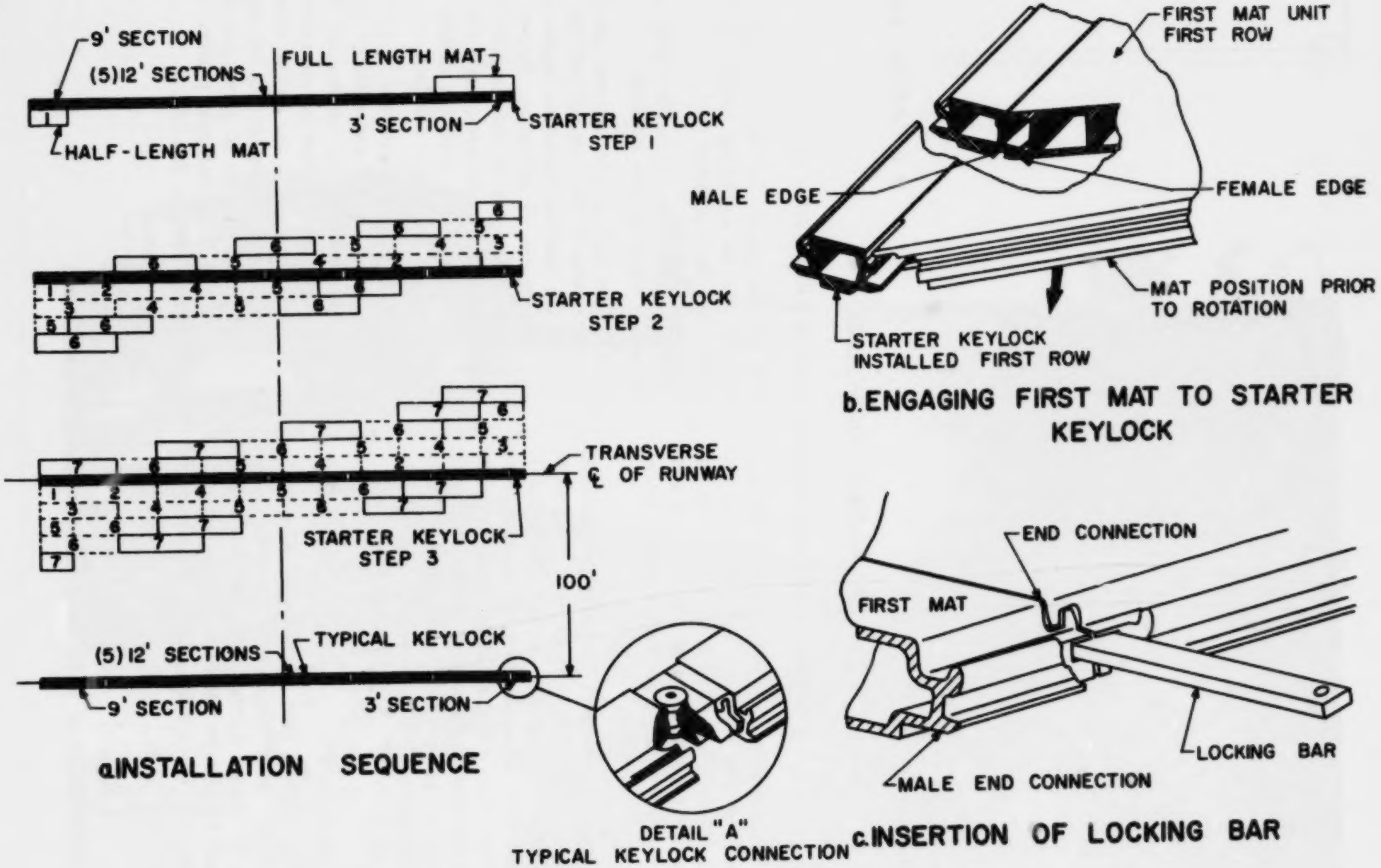
Survey lines are established to guide at least one edge of the section being laid to maintain longitudinal alinement. Panels can be placed on a subgrade crowned as much as 1.5 percent. As the crowned subgrade increases above 1.5 percent, increased difficulty is encountered in making connections between individual panels across the longitudinal centerline of the runway.

b. Lay the starter keylock on the transverse centerline of the runway. A 9-foot keylock is laid at the outer edge followed by 12-foot sections across the runway (fig. 125). The first panel will be placed in position 1 (a, fig. 125) by holding the panel at a 45° angle to the ground so that the female connector is engaged over the male and lowered into position (b, fig. 125). Subsequent panels will be placed left to right in sequence 2, 3, 4, 5, etc., in a stairstep pattern as indicated in a, figure 125. Note that a half-panel is used in alternate runs to provide a staggered pattern. This pattern will be maintained throughout placement. The ends of panels will be locked by inserting the locking bar in the lock bar slot, as shown in c, figure 125. After two to four runs have been placed to insure proper alinement, a second crew can begin placement in the opposite direction (and from the opposite side) using the same placement procedure as that described above.

c. Every 100 feet, install a run of typical keylocks in the matting field (a, fig. 125). This will permit the easy removal of sections for multiple mat replacement. Place a 9-foot typical keylock at the outer edge of the runway with the female end of the keylock alined with the first mat of the preceding row. Additional 12-foot sections are then installed next to the 9-foot section to complete the width of the runway. After laying a run of typical keylock sections across the runway, continue laying matting using the same procedure described above.

336. Anchorage

a. Sides of Runway. Anchor lugs and earth anchors (a and c, fig. 126) are installed every


9' SECTION
(5)12' SECTIONS
FULL LENGTH MAT
3' SECTION
STARTER KEYLOCK STEP 1
HALF-LENGTH MAT
STARTER KEYLOCK STEP 2
TRANSVERSE ℄ OF RUNWAY
STARTER KEYLOCK STEP 3
100'
(5) 12' SECTIONS
TYPICAL KEYLOCK
9' SECTION
3' SECTION
FIRST MAT UNIT FIRST ROW
MALE EDGE
FEMALE EDGE
MAT POSITION PRIOR TO ROTATION
STARTER KEYLOCK INSTALLED FIRST ROW
END CONNECTION
FIRST MAT
LOCKING BAR
MALE END CONNECTION

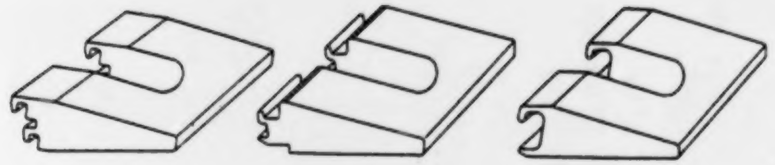
a. INSTALLATION SEQUENCE

DETAIL "A"
TYPICAL KEYLOCK CONNECTION

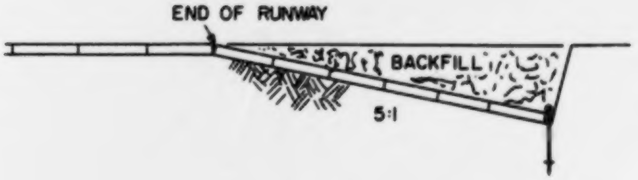
b. ENGAGING FIRST MAT TO STARTER KEYLOCK

c. INSERTION OF LOCKING BAR

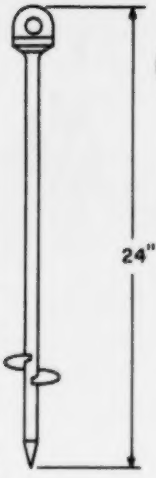
Figure 125 (Superseded) *Placement details for AM2 and MX18 mat.*



a. ANCHOR LUGS



b. END OF RUNWAY ANCHORAGE



c. EARTH ANCHOR

Figure 126 (Superseded) *Anchorage details for AM2 and MX18 mat.*

fourth to sixth run on both sides of the runway. An anchor lug is placed on the edge of the mat and an earth anchor fitted to the slot in the lug. The earth anchor is screwed into the earth until it seats firmly in the lug. The lug is then locked in place using a short lock bar.

b. Ends of Runway. The earth is excavated at each end of the runway to form a 5:1 slope for the full width of the runway (b, fig. 126). Six full runs of panel are then placed down the slope (fig. 127) and anchored in place with a minimum of two anchor lugs and earth anchors per panel. The trench is then backfilled and compacted to match the original subgrade contour.

337. Transitions

a. 90° Angles. Two methods may be used to effect a 90° turn. Either the H connector or one of the special overlap and male or underlap and male connectors will be used, as illustrated in figure 128. When using the H connector, the ends of the panels in the first run of the taxiway will be connected before sliding the panels into the connector.

b. Variable Angles. Variable angles may b formed by either of two methods.

(1) The ends of the taxiway panels that intersect the runway will be cut at the desired transition angle and slid into the H connector. Panels in the shortest run of the taxiway will be placed first, progressing to the second shortest run, until the normal width of the taxiway is reached.

(2) Either the H connector or one of the special overlap and male or underlap and male special connectors will be used. The first run in the taxiway will be connected to the special connector. Each run thereafter will be staggered 2, 3, or 4 feet to form any desired angle in a stairstep pattern at the panel end (a, fig. 128).

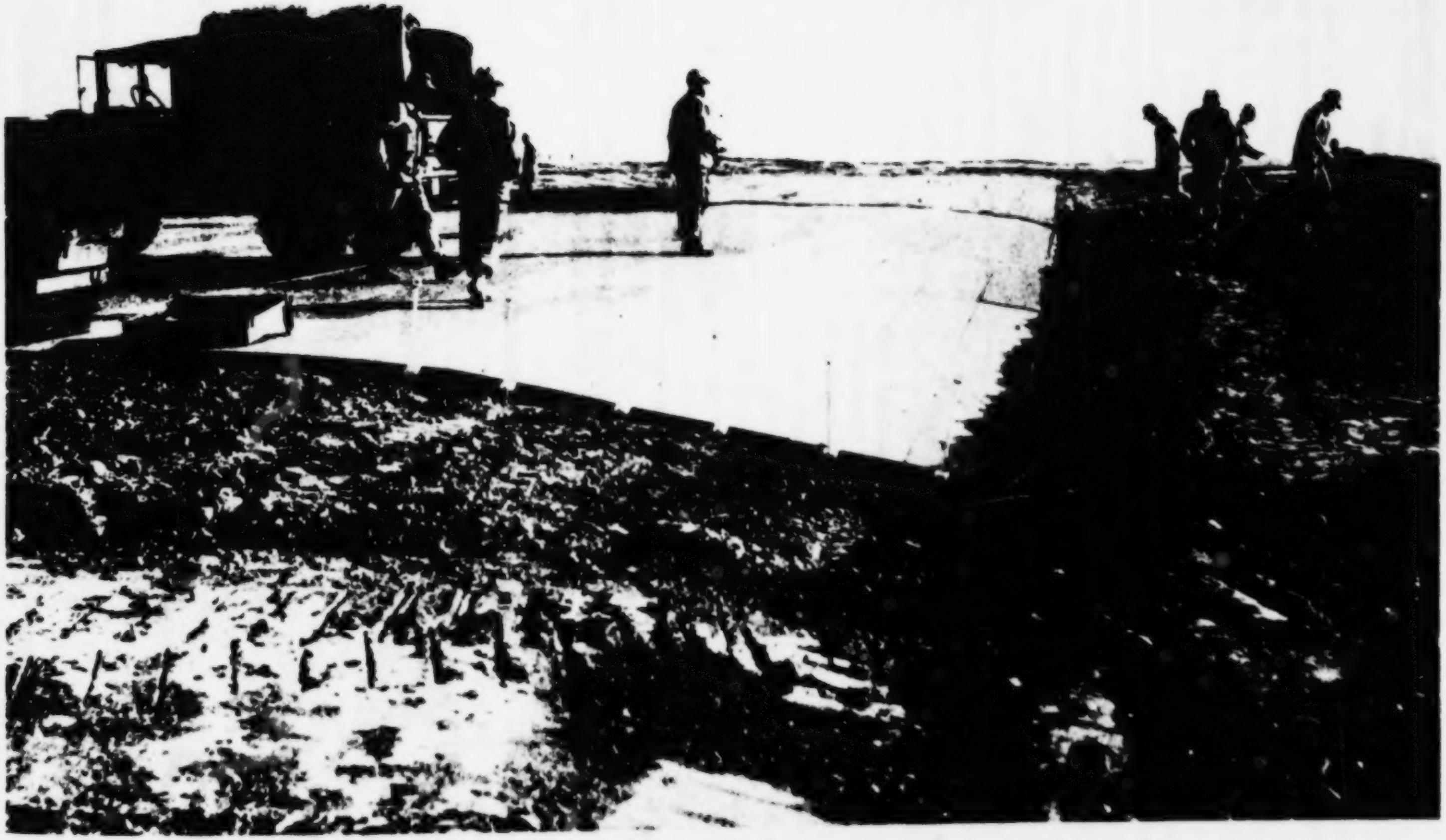
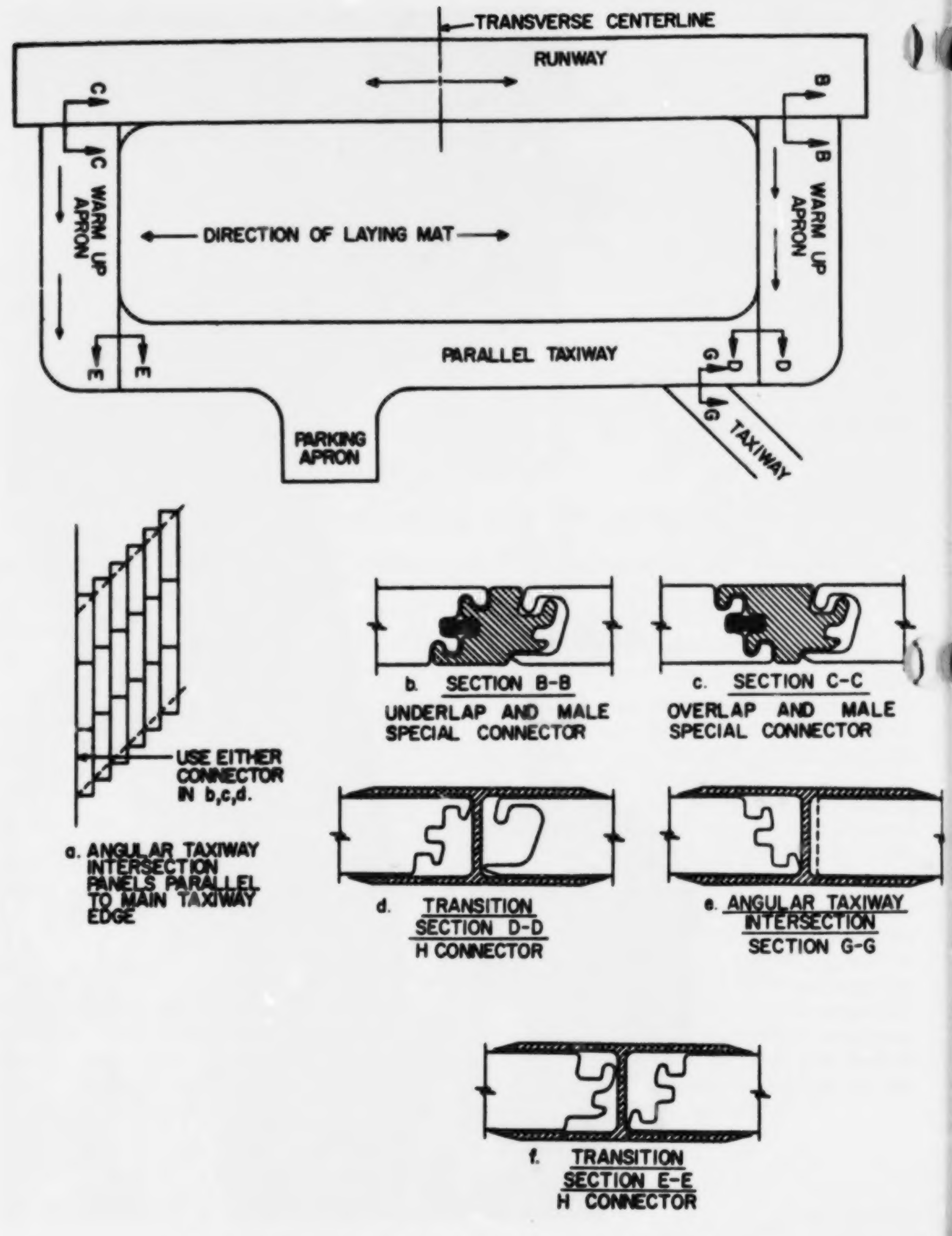


Figure 127 (Superseded) ***AM2 anchor ramp at end of runway.***



TRANSVERSE CENTERLINE
RUNWAY
C
C
B
B
WARM UP APRON
WARM UP APRON
DIRECTION OF LAYING MAT
E
E
PARALLEL TAXIWAY
G
D
D
G
TAXIWAY
PARKING APRON
USE EITHER CONNECTOR IN b,c,d.

a. ANGULAR TAXIWAY INTERSECTION PANELS PARALLEL TO MAIN TAXIWAY EDGE

b. SECTION B-B
UNDERLAP AND MALE SPECIAL CONNECTOR

c. SECTION C-C
OVERLAP AND MALE SPECIAL CONNECTOR

d. TRANSITION SECTION D-D
H CONNECTOR

e. ANGULAR TAXIWAY INTERSECTION SECTION G-G

f. TRANSITION SECTION E-E
H CONNECTOR

Figure 128 (Superseded) *Transition details for AM2 and MX18 mat.*

Section V. MX19 MAT

38. Description

The MX19 mat is a sandwich-type structure containing an aluminum honeycomb core 1.375 inches thick bonded top and bottom to 0.063-inch-thick aluminum plates, as shown in figure 128.1. The connectors are bonded to the edges of the core with a potting compound and are welded to the top and bottom plates. Two edges of the panel have an overlap-and underlap-type joint that will be connected and locked to adjoining panels with a lock bar. The other two edges have a hinge-type connection. The panels are 1.5 inches thick, 48.1 inches square, and weigh approximately 68 pounds. A panel covers approximately 16.7 square feet and weighs 4.1 pounds per square foot. The panels can be placed at a rate of 350 square feet per man-hour. The MX19 mat qualifies as a medium-duty mat based both on performance and weight. The MX19 is packaged in pallets containing 32 full panels and 32 locking bars. Major components of the MX19 system are half-width mats and repair mats, all of which are packaged in specially marked pallets. In computing material requirements, N_w (equation 17–1) is rounded up to the nearest full panel and a waste factor of 10 percent for new panels and 15 percent for recovered panels is used.

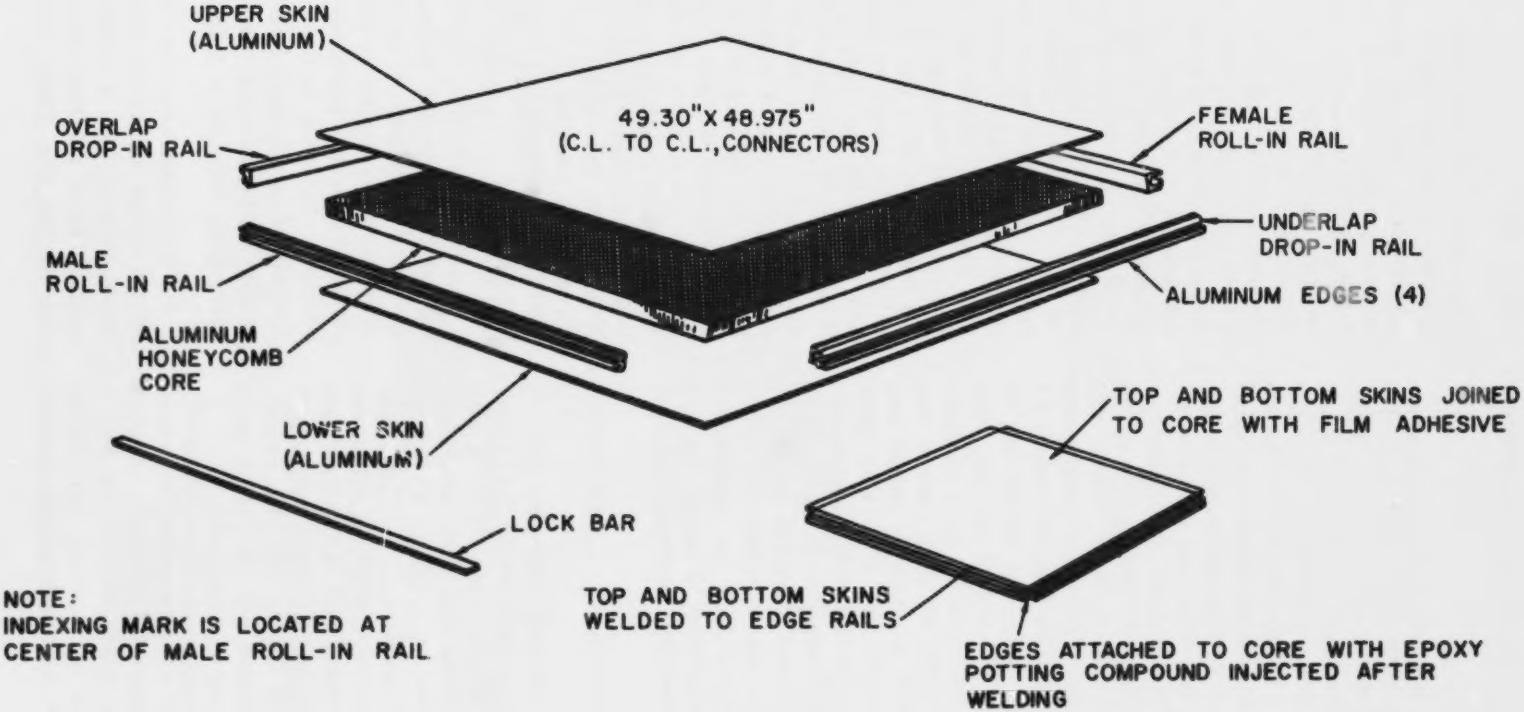
339. Placement

a. The general sequence for placement of MX19 is the same as for AM2 or MX18 mat. A special starter adapter (fig. 128.2) is used to form the transverse line from which mat placement progresses in opposite directions. The use of starter adapters at the transverse centerline of the runway permits simultaneous placement of mat toward each end. Survey base lines are established to guide both outer edges of the section being laid to maintain longitudinal alinement. Panels can be placed on a crowned subgrade up to 3 percent.

b. Lay the starter adapter on the transverse centerline of the runway. The starter adapters are locked together end-to-end starting with a half length section to establish the correct relationship to mat joints across the runway (fig. 128.2). The first panel will be placed in position 1 (a, fig. 128.3) by engaging the overlap edge with the starting adapter. Subsequent panels in the first row (positions 1, 3, 7, etc.) will be placed in a similar manner. The second panel will be held at a 45° angle to the ground so that the female connector can be engaged over the male and dropped into position to engage the underlap and overlap edges. Remaining panels will be placed right to left in sequences 4, 5, 6, and 8, 9, 10, etc., in a stairstep pattern as indicated in figure 128.4. Note that No. 2 panel is a half-panel; half-panels will be used in alternate rows at the starting connector to provide a staggered pattern. After laying a mat, a lock bar is inserted in the lock bar slot (b. fig. 128.3) to lock it to the adjacent mat. Because of unevenness of the subgrade or because of mat warpage, it may be an aid to lift one corner of a mat in the adjacent row, using a shovel point or small pry bar. This will aline lock bar slots to aid in lock bar insertion. Lock bar retainers are installed in the two edge rows of mats to prevent lock bars from working out of position (c, fig. 128.3). Retainers are installed in a hole in the inboard end of the lock bar and clinched in place by flattening the concave top side with a punch. A satisfactory punch can be made by cutting a 5-inch length of $\frac{5}{16}$- by $\frac{7}{8}$-inch steel bar stock. The inboard end of the lock bar is reached through the opening in the runway surface caused by corresponding corner notches in the mat panels.

c. After two to four runs have been placed and proper alinement insured, a second crew can begin placement in the opposite direction using the same placement procedure described above. If sufficient personnel and material are available, one crew is used for each run. A distance of several mats is kept between crews to allow adequate work space and prevent one crew from delaying a following crew.

d. Field access adapters (fig. 128.5) are installed in the staggered transverse joints between mats to form a V-shaped line with the point of the V pointing *toward* the transverse starting line (fig. 128.5). These adapters are


UPPER SKIN (ALUMINUM)
49.30"X 48.975" (C.L. TO C.L.,CONNECTORS)
OVERLAP DROP-IN RAIL
FEMALE ROLL-IN RAIL
UNDERLAP DROP-IN RAIL
MALE ROLL-IN RAIL
ALUMINUM EDGES (4)
ALUMINUM HONEYCOMB CORE
TOP AND BOTTOM SKINS JOINED TO CORE WITH FILM ADHESIVE
LOWER SKIN (ALUMINUM)
LOCK BAR
TOP AND BOTTOM SKINS WELDED TO EDGE RAILS
EDGES ATTACHED TO CORE WITH EPOXY POTTING COMPOUND INJECTED AFTER WELDING

NOTE:
INDEXING MARK IS LOCATED AT CENTER OF MALE ROLL-IN RAIL

Figure 128.1 (Added) *Exploded view of MX19 full mat.*

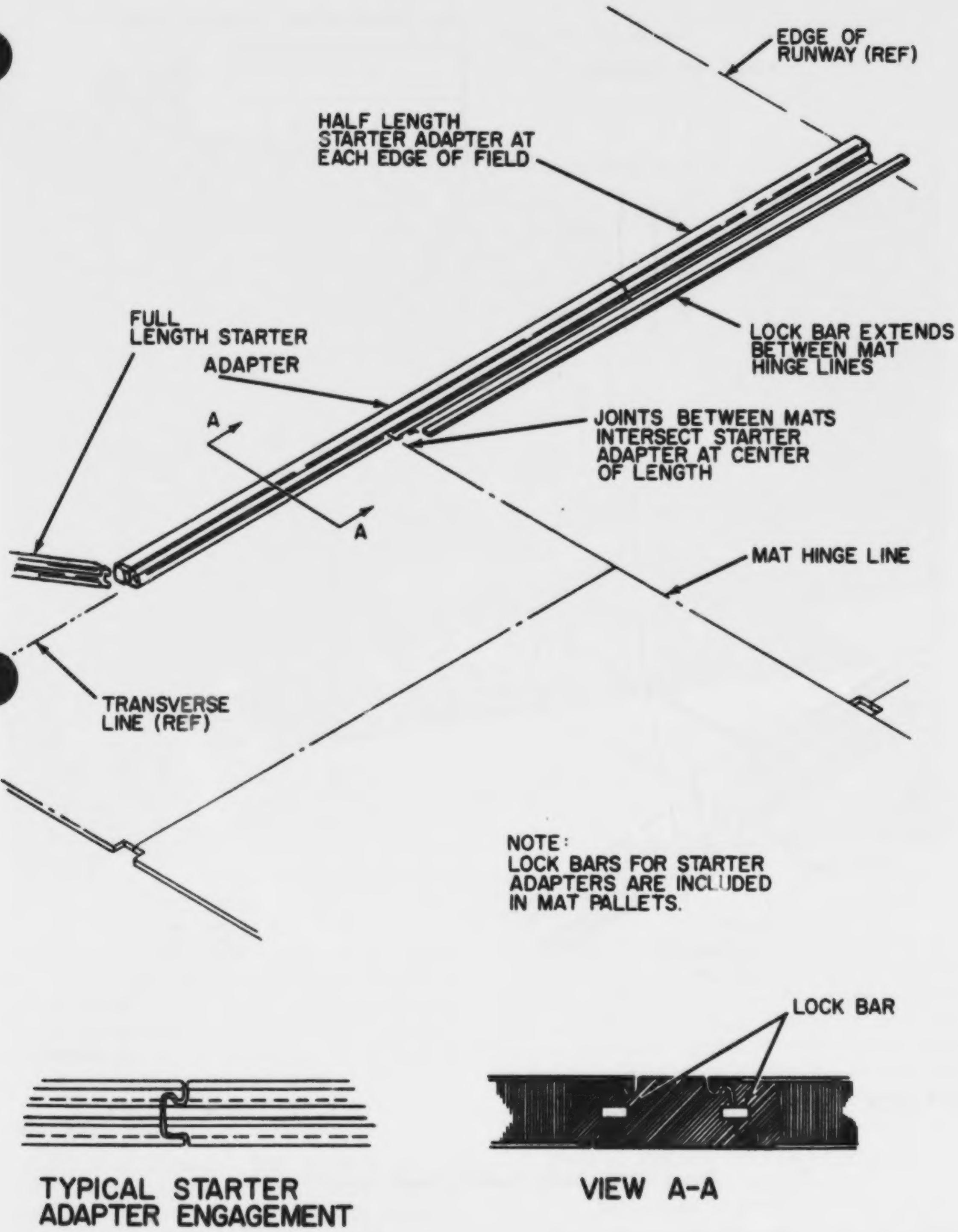
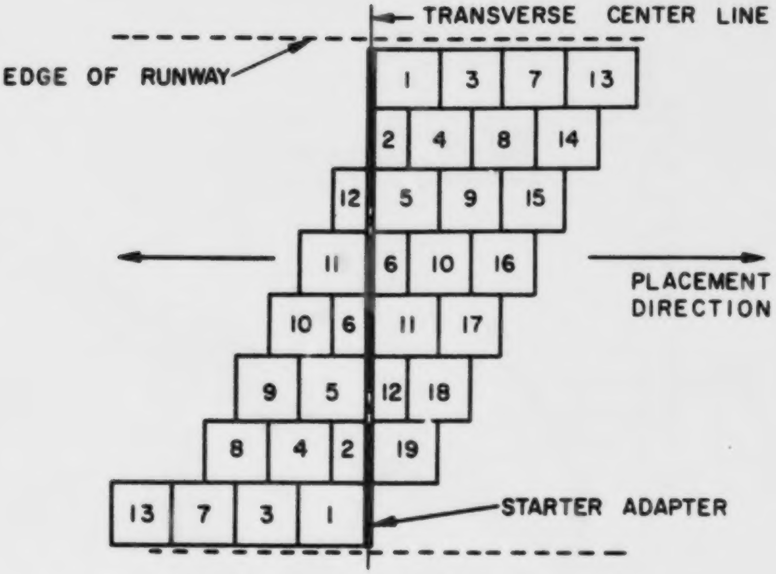
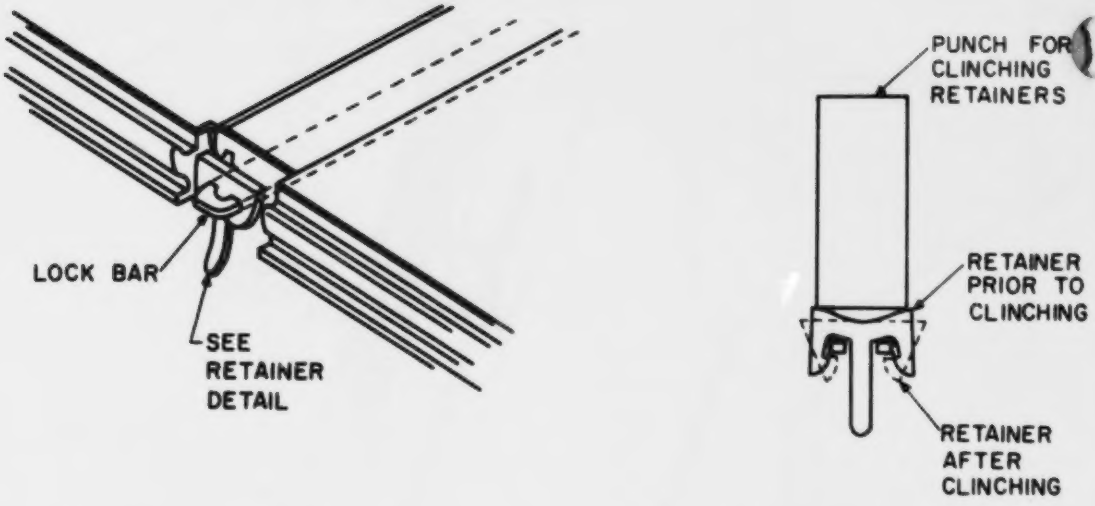

EDGE OF RUNWAY (REF)
HALF LENGTH STARTER ADAPTER AT EACH EDGE OF FIELD
FULL LENGTH STARTER ADAPTER
LOCK BAR EXTENDS BETWEEN MAT HINGE LINES
A
JOINTS BETWEEN MATS INTERSECT STARTER ADAPTER AT CENTER OF LENGTH
A
MAT HINGE LINE
TRANSVERSE LINE (REF)
NOTE: LOCK BARS FOR STARTER ADAPTERS ARE INCLUDED IN MAT PALLETS.
LOCK BAR
TYPICAL STARTER ADAPTER ENGAGEMENT
VIEW A-A

Figure 128.2 (Added) *Starter adapter installation detail.*


TRANSVERSE CENTER LINE
EDGE OF RUNWAY
1
3
7
13
2
4
8
14
12
5
9
15
11
6
10
16
10
6
11
17
9
5
12
18
8
4
2
19
13
7
3
1
PLACEMENT DIRECTION
STARTER ADAPTER

a. PLACEMENT SEQUENCE


LOCK BAR
SEE RETAINER DETAIL
PUNCH FOR CLINCHING RETAINERS
RETAINER PRIOR TO CLINCHING
RETAINER AFTER CLINCHING

b. LOCK BAR AND RETAINER INSTALLED

c. RETAINER DETAIL

Figure 128.3 (Added) *Placement details for MX19 mat.*

aluminum alloy bars with one overlap and one underlap drop-in edge. An additional lock bar is required for each adapter. Installation of the access adapters permits the runway to be broken by withdrawing the access adapter from between mats. This allows nondestructive

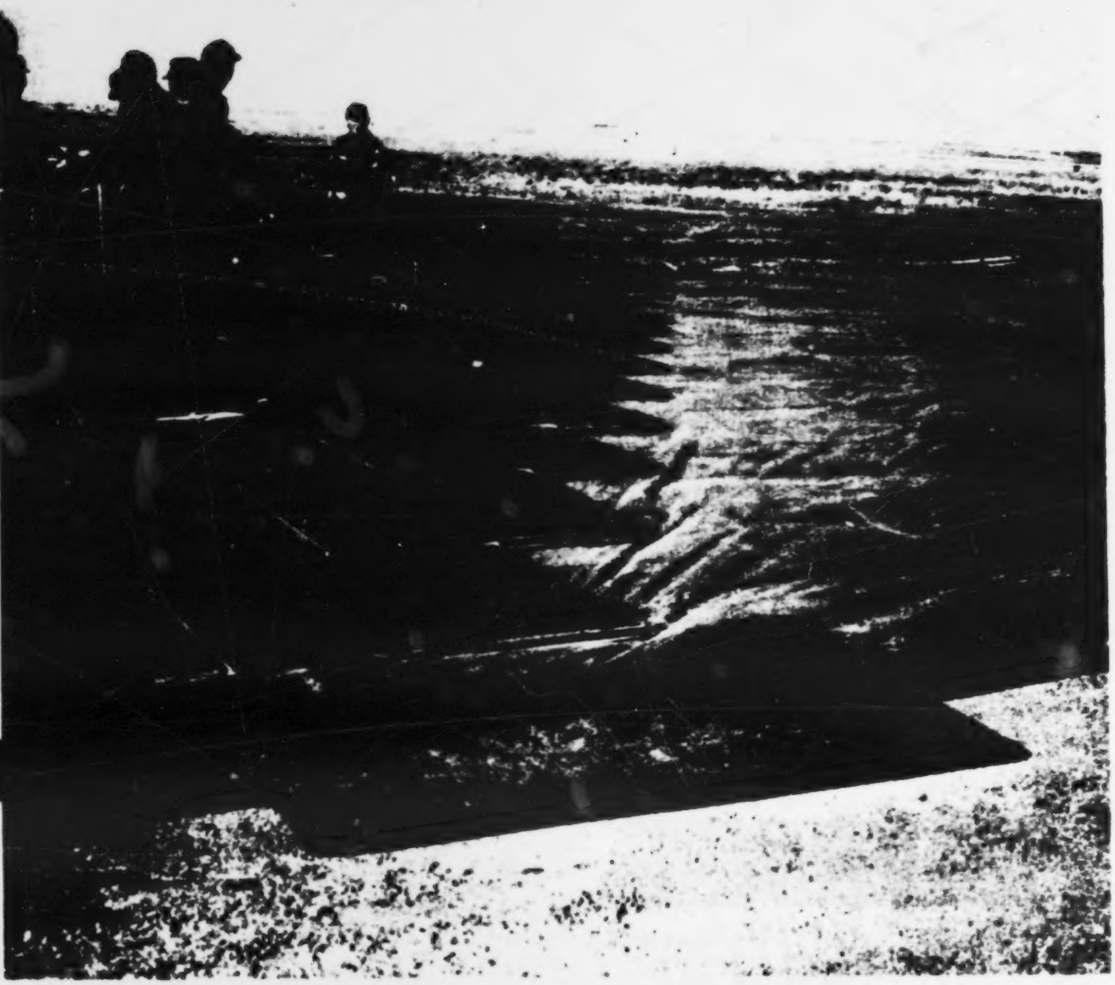


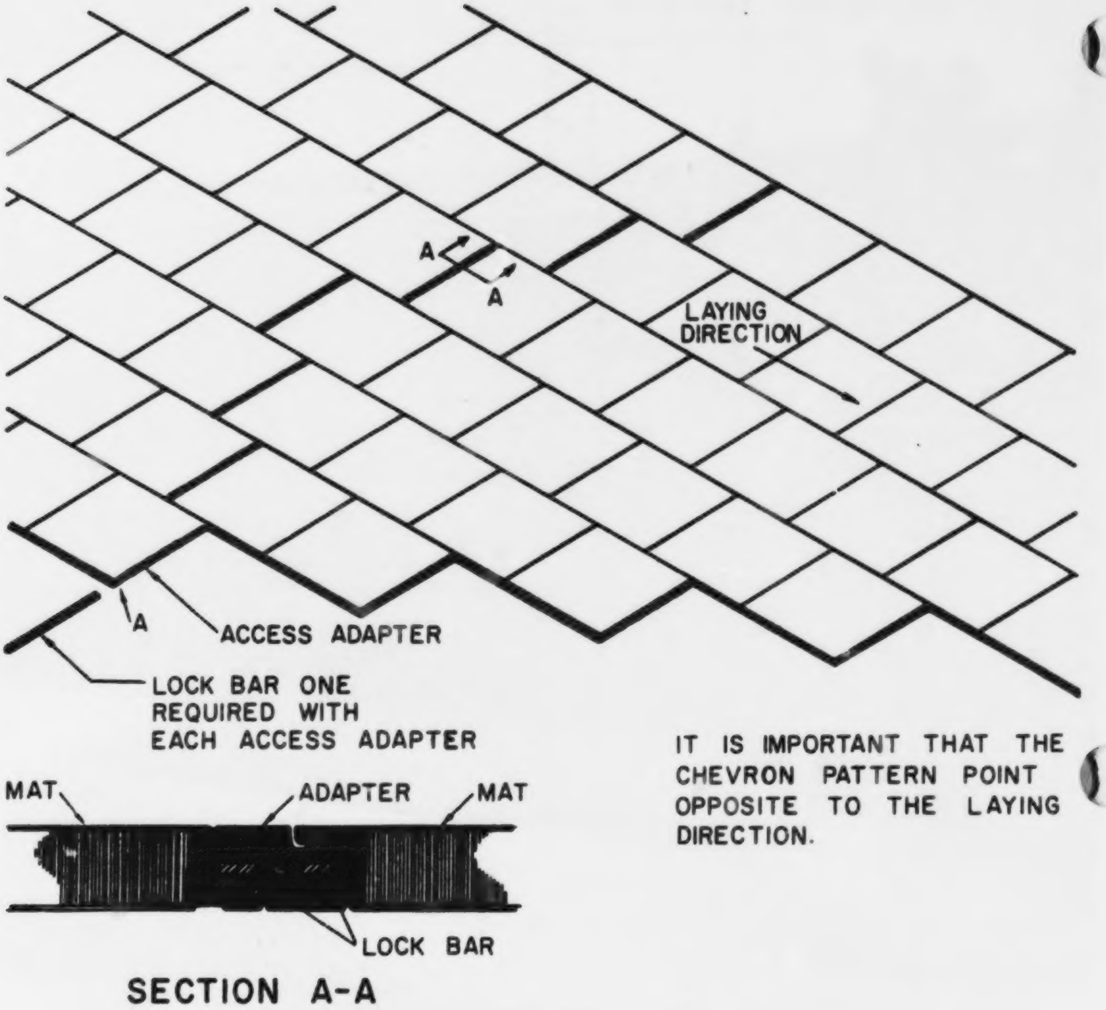
Figure 128.4 (Added) *Stairstep placement pattern of MX19 mat.*

removal and reinstallation of mats for access to replace damaged mats or make repairs to the subgrade. Field access adapters pattern should be established at 100-foot intervals along the runway to minimize the pickup of panels to reach a damaged area.

340. Anchorage

a. Sides of Runway. Mat anchors are installed at the center of the outside edge of alternate mats on each side of the runway. An anchor lug (fig. 128.6) is placed in position on the edge of the mat. The point of the earth nchor is then located in its proper position in the slot of the anchor lug. The lug is removed and the earth anchor is screwed into the earth until the plates are below the surface. The anchor lug is then reinstalled and the anchor is screwed further in until it seats itself in the lug. The drop-in anchor lug fittings are locked by spreading the forked end of the short lock bar.

b. Ends of Runway. The earth is excavated at each end of the runway to form a sloped subgrade to a depth of 26 inches (fig. 128.6). Two full runs are then placed down the slope using the turndown adapter. The turned down underlap edge of the adapter is set at an angle



A
A
LAYING DIRECTION
A
ACCESS ADAPTER
LOCK BAR ONE REQUIRED WITH EACH ACCESS ADAPTER
IT IS IMPORTANT THAT THE CHEVRON PATTERN POINT OPPOSITE TO THE LAYING DIRECTION.
MAT
ADAPTER
MAT
LOCK BAR
SECTION A-A

Figure 128.5 (Added) *MX19 Field access adapter detail.*

of 15° down from the plane of the overlap edge. After the mats are laid, anchor each mat with one anchor lug and earth anchor. Backfill the trench and compact to match the original subgrade contour.

341. Transition

a. 90° Angles. To form a 90° turn, as from a runway onto a taxiway, special turning adapters are used. The aluminum alloy turning adapters consist of underlap male adapters, overlap male adapters, and female underlap adapters (fig. 128.7).

(1) The underlap male turning adapters are used to adapt an intersecting runway or taxiway to the female edge of a runway. A lock bar with two retainers is used to secure the drop in side of the adapter to a following mat.

(2) The overlap male turning adapters are used to rotate the mat lay by 90°. A lock bar and two retainers are required to attach the adapters to the underlap edges.

(3) The female underlap turning adapters are used for attachment of an inter-

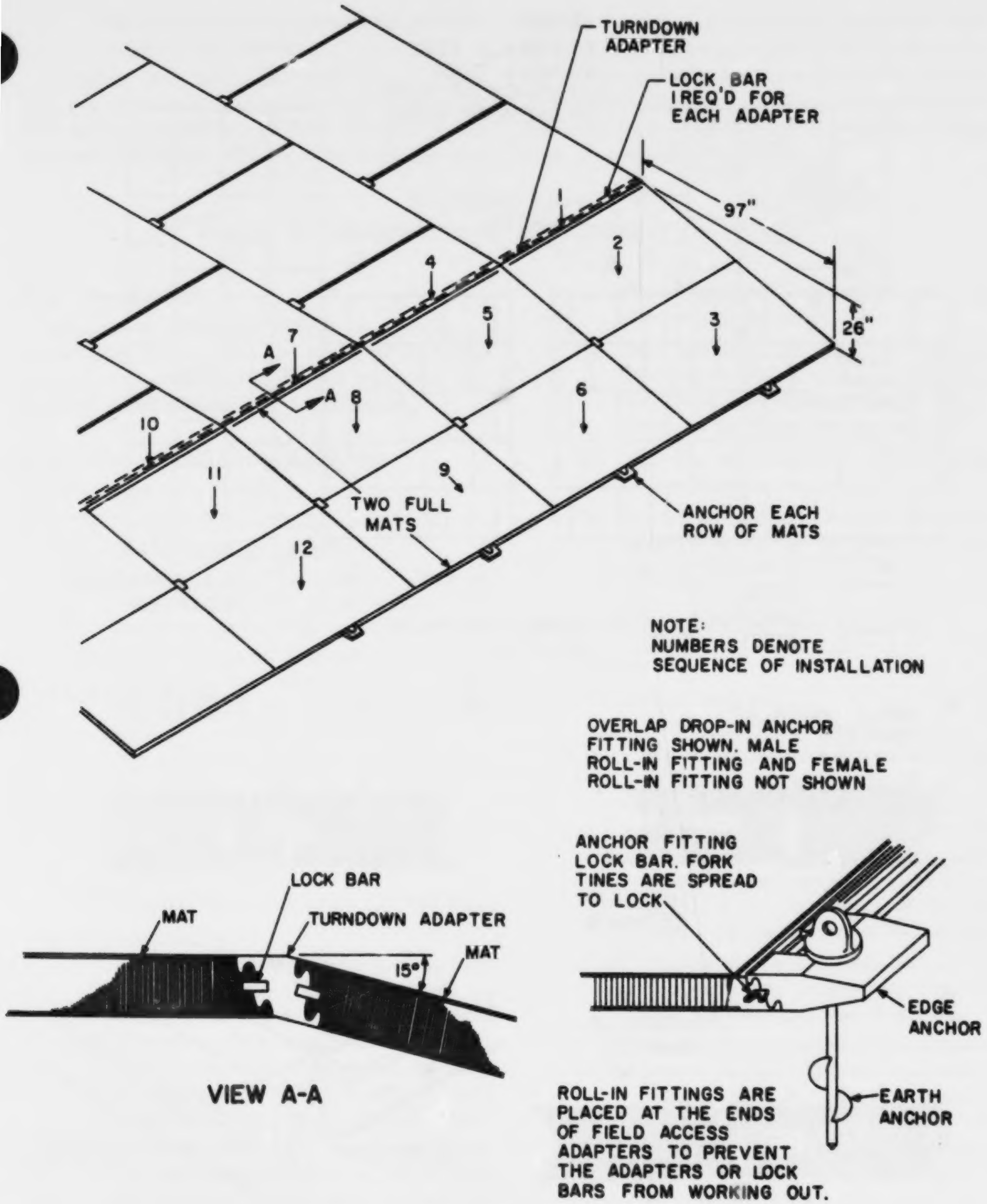

TURNDOWN ADAPTER
LOCK BAR 1 REQ'D FOR EACH ADAPTER
97"
26"
1
2
3
4
5
6
7
8
9
10
11
12
A
A
TWO FULL MATS
ANCHOR EACH ROW OF MATS
NOTE: NUMBERS DENOTE SEQUENCE OF INSTALLATION
OVERLAP DROP-IN ANCHOR FITTING SHOWN. MALE ROLL-IN FITTING AND FEMALE ROLL-IN FITTING NOT SHOWN
LOCK BAR
MAT
TURNDOWN ADAPTER
15°
MAT
VIEW A-A
ANCHOR FITTING LOCK BAR. FORK TINES ARE SPREAD TO LOCK
EDGE ANCHOR
EARTH ANCHOR
ROLL-IN FITTINGS ARE PLACED AT THE ENDS OF FIELD ACCESS ADAPTERS TO PREVENT THE ADAPTERS OR LOCK BARS FROM WORKING OUT.

Figure 188.6 (Added) *MX19 Anchorage details.*

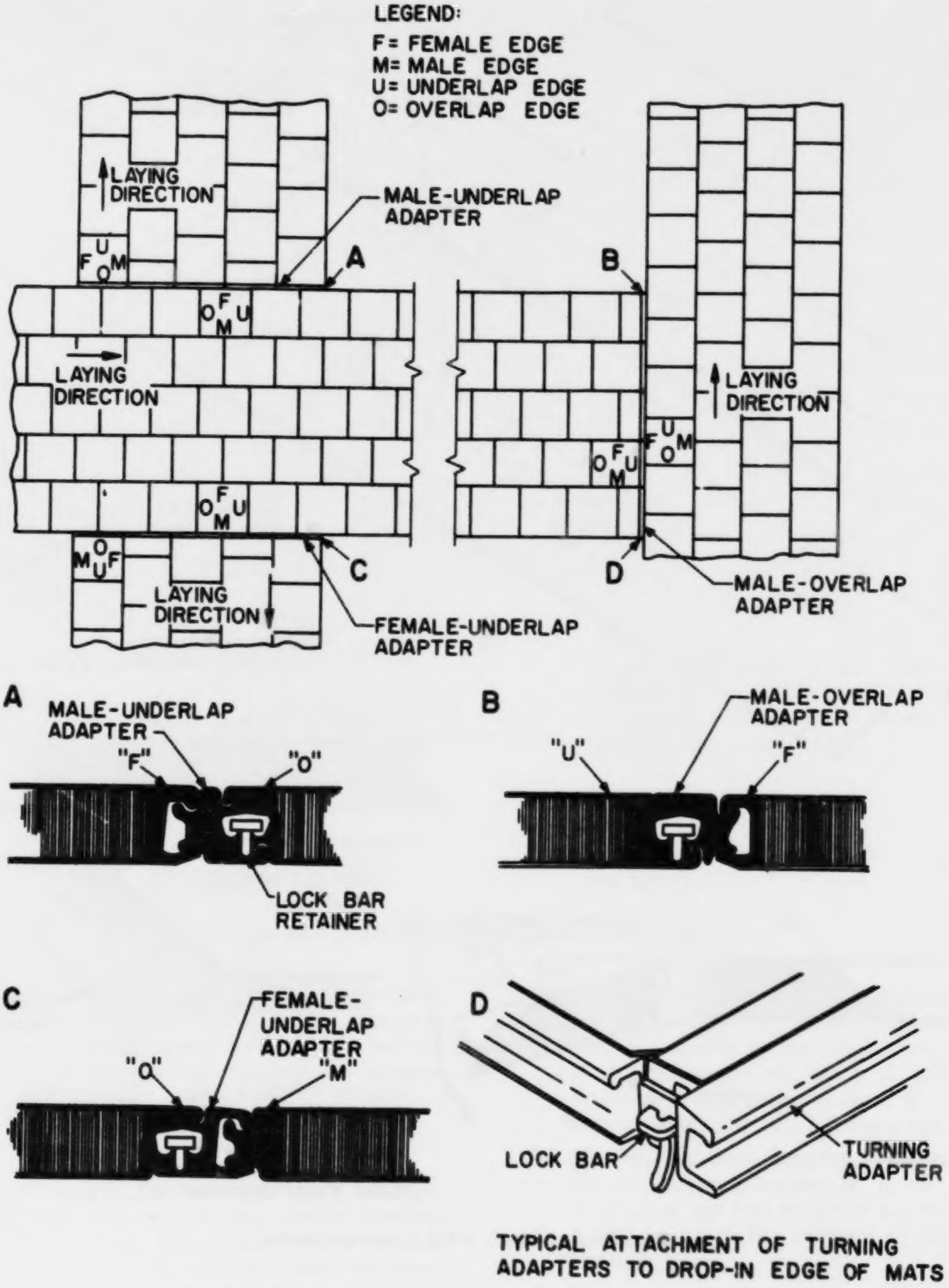

LEGEND:
F= FEMALE EDGE
M= MALE EDGE
U= UNDERLAP EDGE
O= OVERLAP EDGE
LAYING DIRECTION
MALE-UNDERLAP ADAPTER
A
B
C
D
F U M O
O F U M
LAYING DIRECTION
LAYING DIRECTION
O F U M
F U M O
O F U M
M O U F
LAYING DIRECTION
FEMALE-UNDERLAP ADAPTER
MALE-OVERLAP ADAPTER
A
MALE-UNDERLAP ADAPTER
"F"
"O"
LOCK BAR RETAINER
B
MALE-OVERLAP ADAPTER
"U"
"F"
C
FEMALE-UNDERLAP ADAPTER
"O"
"M"
D
LOCK BAR
TURNING ADAPTER
TYPICAL ATTACHMENT OF TURNING ADAPTERS TO DROP-IN EDGE OF MATS

Figure 128.7 (Added) *MX19 Turning adapter applications.*

secting runway or taxiway to the male edge of the runway.

b. Fillets. Full mats are used to lay fillets between intersecting runways and taxiways. The normal staggered pattern is maintained and rows are terminated so as to form the outline of the fillet. A backlaying technique may be used in fillet areas where it is necessary to lay in the opposite direction from the original laying direction. Mats are backlaid by engaging the male edge of mat being layed with female edge of previously installed mat.

Section VI. REMOVAL AND REPLACEMENT OF PANELS

342. Introduction

Removal of individual panels or sections of panels may be required for repair of the subgrade, replacement of damaged mats, or replacement for preventive maintenance.

342.1 M6, M8, M8A1, and M9 Mat

a. Removal.

(1) Unlock the end-connector at both ends of the panel to be removed.

(2) Remove the side-connector locking lugs that hold the panel. (Break the welds on the locking lugs of the M8).

(3) Drive the panel laterally (approx 1 in.) until the side-connector hooks are centered in the side-connector slots.

(4) Pry the side-connector hooks out of the slots.

(5) Drive the panel laterally to clear the end from the overlapping end of the adjacent panel.

(6) Remove the panel from the runway.

b. Replacement.

(1) Remove the side-connector locking lugs of a new panel (break the welds on the M8) to allow the panel to slide laterally when positioned properly. Orient the new panel in all respects so that it will be in the approximate position in the run of the old panel.

(2) Drive the end of the new panel under the end of the adjacent panel so that the adjacent panel will overlap the new panel. The panel will then be in its approximate final position.

(3) Adjust the panel so as to aline the side-connector hooks with the side-connector slots. Engage the two by hammering together.

(4) Drive the panel laterally (in the same direction in which panels in the same run were slid during initial placement) to hook the side connection.

(5) Lock the end-connector at both ends of the panel.

(6) Replace and engage the side-connector locking lugs in the lock lug slot (reweld on the M8).

342.2. MX18B, MX18C, and AM2 Mat

a. Removal.

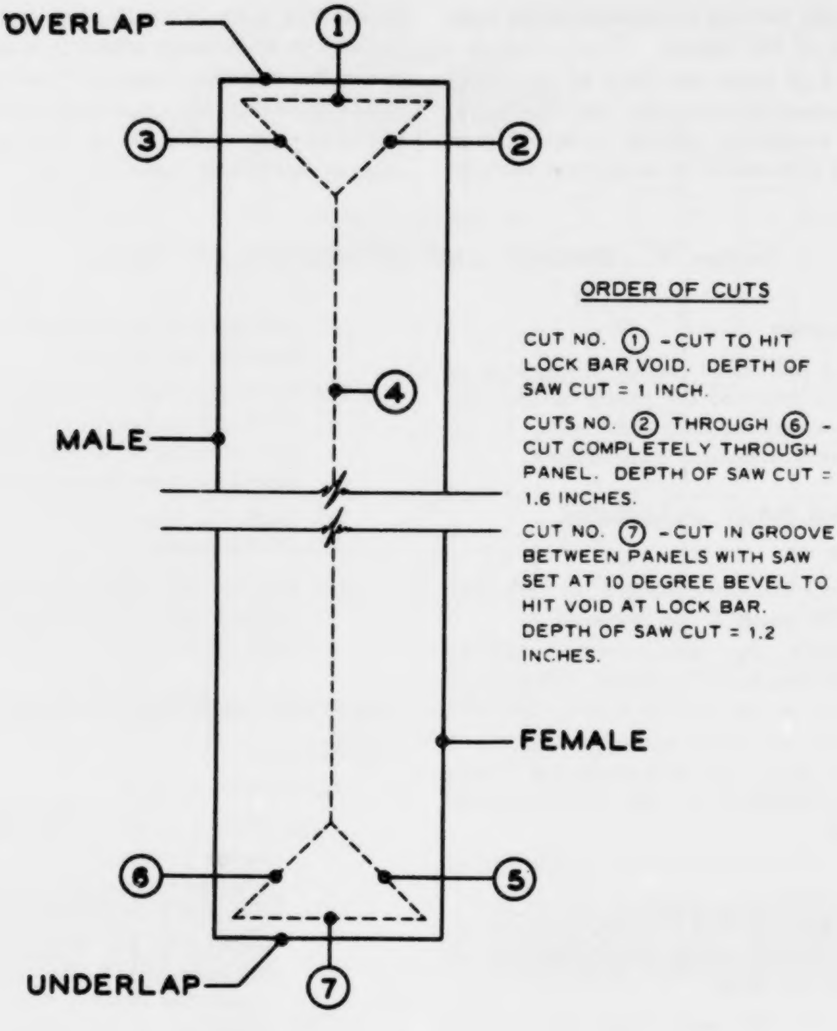
(1) *Sliding method.*

(*a*) With a tooth of the harrow on a motor grader or with other power equipment engage a panel end in the same run with the damaged panel and force the entire run to slide out until the damaged panel clears the runway edge. A light application of oil poured along the sliding joints will assist in removal.

(*b*) Disconnect at the ends all panels that have been pulled from the runway by removing the lock bars.

(*c*) Discard the damaged panel. Connect a new panel in its place and lock at the end with the adjacent panel in the run. With a tooth of the motor grader harrow engage the panel end and slide the panel until only 2 to 4 inches of the new panel protrudes past the edge of the runway.

(*d*) Reinstall succeeding panels as in (*c*) above until all panels in the run are in their original position.



ORDER OF CUTS

CUT NO. ① - CUT TO HIT LOCK BAR VOID. DEPTH OF SAW CUT = 1 INCH.

CUTS NO. ② THROUGH ⑥ - CUT COMPLETELY THROUGH PANEL. DEPTH OF SAW CUT = 1.6 INCHES.

CUT NO. ⑦ - CUT IN GROOVE BETWEEN PANELS WITH SAW SET AT 10 DEGREE BEVEL TO HIT VOID AT LOCK BAR. DEPTH OF SAW CUT = 1.2 INCHES.

Figure 128.8 **(Added)** *Cutting method for removing AM2 and MX18 mat.*

(2) ***Cutting method.***

(*a*) Cut the damaged panel in seven places, as shown in figure 128.8.

(*b*) With a pry bar, force up cut No. 4 and hinge out one side of the cut panel.

(*c*) Force up and hinge out the opposite side.

(*d*) Force out the lock bars, and remove the two triangle parts by forcing down or up and out. (The adjacent panels can be pried up so that the triangular parts can be removed more easily).

(3) ***Typical keylock method.*** **Where a large area of the runway or taxiway must be repaired, the section of typical keylocks nearest the repair area is removed. Since placement of typical keylock sections is every 100 feet, no more than 50 feet of runway need be removed to reach the damaged area.**

(*a*) Remove the first typical keylock sec-

tion by loosening the socket head screw at the first inboard connection. This screw need only be loosened until it is free of the male end of the adjoining keylock (about $^7/_{16}$ of an in.). Do not remove the screw completely since it is designed to be self-retaining.

(*b*) Insert the prong of the keylock removal tool under the turned down lip of the female connector and slide the keylock from its position. Loosen and remove the remaining keylock sections in the same manner.

(*c*) Using blocking and prybars, the first run of mats must be lifted high enough to allow the locking bar to clear. To prevent warping of mats, it is recommended that the entire run of mat be lifted at the same time. With the run of mats raised, insert a bent rod in the locking bar hole and remove each locking bar.

(*d*) With the clearance now provided, removal of the remainder of the mat is readily accomplished.

b. Replacement.

(1) *Repair mat method.*

(*a*) Use a special panel and accessories to replace the damaged panel. Figure 128.9 shows the special panel and accessories unassembled and assembled.

(*b*) Place the accessories in the void and connect and aline in such a way that the panel will fit on top of (overlap) two edges and hinge on a third edge. Figure 128.10 shows the accessories assembled and connected on one side in the void area.

(*c*) Engage the hinge on the panel and drop into position. The normal underlapping end of the panel contains a lock bar, recessed to prevent interference when dropped into position and secured with two setscrews. Remove screws and use a pointed rod to work the lock bar into the slot of the adjacent panel. Replace the setscrews and screw down along the side edge of the lockbar to prevent the bar from disengaging.

(*d*) Place the top rail for the side and secure with countersunk Allenhead screws.

(2) *Typical keylock method.* Reinstall matting over the repair area, using the mat laying procedure described in paragraph 335, until the last run of matting is in place. Raise this last run of matting in unison, using one prybar per panel, until sufficient clearance is obtained to permit installation of locking bars. Install all locking bars in the last run of mat then insert the typical keylocks in the reverse order in which they were removed. Use wood blocking between hammer and connector if it is necessary to drive sections into place.

342.3 MX19 Mat

a. Removal.

(1) *Field access adapter method.*

Note. Field access adapters have an overlap and underlap side. Only mats on the overlap side of the field access adapters can be removed by this method (fig. 128.5).

(*a*) Remove lock bar retainers and lock bars from the overlap side of field access adapter at edge of field.

(*b*) Slide adapter from position, using suitable tool attached to hole in end of adapter to aid in removal.

(*c*) Remove mat by removing lock bar retainer and lock bar.

(*d*) Remove next adapter and mat.

(*e*) Repeat these procedures as required until point is reached where a series of mats may be removed with or without removal of additional adapters to reach damaged area.

(2) *Cutting method.*

(*a*) Cut mat with portable saw as shown in figure 128.11. Use saw blade with carbide tip blade, lubricated to prevent chips sticking

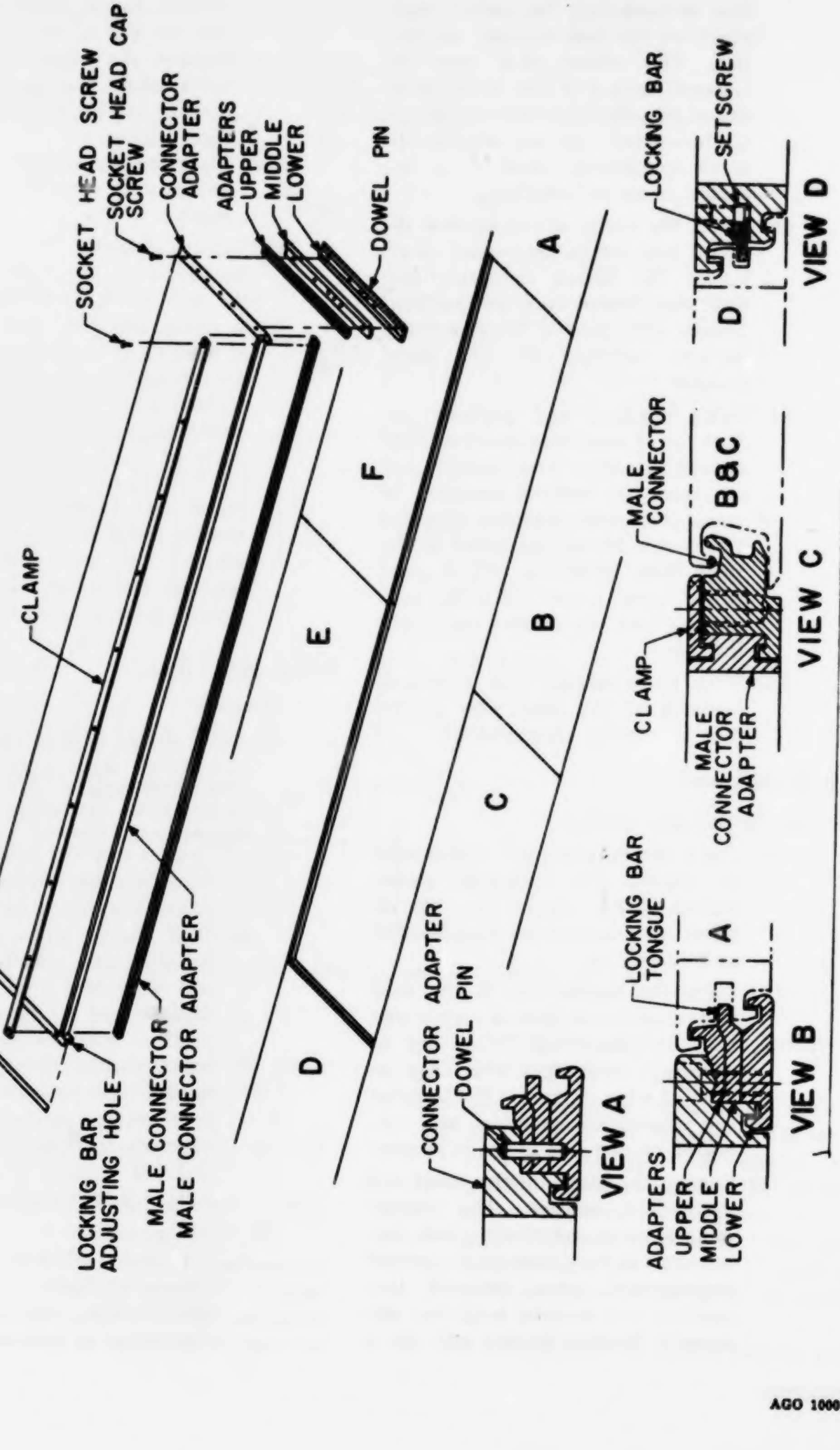

LOCKING BAR
SET SCREW
LOCKING BAR CONNECTOR
CLAMP
SOCKET HEAD SCREW
SOCKET HEAD CAP SCREW
CONNECTOR ADAPTER
ADAPTERS
UPPER
MIDDLE
LOWER
DOWEL PIN
LOCKING BAR ADJUSTING HOLE
MALE CONNECTOR
MALE CONNECTOR ADAPTER
D
E
F
C
B
A
CONNECTOR ADAPTER
DOWEL PIN
VIEW A
ADAPTERS
UPPER
MIDDLE
LOWER
LOCKING BAR TONGUE
A
VIEW B
CLAMP
MALE CONNECTOR ADAPTER
MALE CONNECTOR
B&C
VIEW C
LOCKING BAR
SETSCREW
D
VIEW D

Figure 128.9 (Added) Replacement panel and accessories for AM2 and MX18 mat.

Figure 128.10 (Added) *Accessories in position for replacing AM2 panel.*

to blade. Make first cut on overlap edge of mat along line No. 1, with saw blade set to make a cut 1$^{1}/_{16}$ inch deep and $^{13}/_{16}$ inch from edge of rail flange. A guide such as a strip of plywood should be used to obtain an accurate cut. If cut deviates toward edge, blade may become jammed when it contacts the loose lock bar in the joint; if cut deviates away from edge, the lock bar pocket will not be exposed, resulting in additional work to remove the bar. Insure that ends of cuts do not extend into adjacent mats.

(*b*) Make second cut along line No. 2. Set saw to cut $^{7}/_{8}$ inch deep, with blade set at angle of 30°. Start the cut $^{1}/_{4}$ inch from edge of upper surface of mat. With this setup, the saw will penetrate lock bar cavity and permit lower lip of underlap rail to be rolled out of its groove.

(*c*) Set saw to depth of 1$^{1}/_{16}$ inch, with blade at angle of 90°. Cut through the mat along lines No. 3, 4, and 5.

(*d*) Remove small triangular piece created by cut on line No. 5.

(*e*) Pry up the triangular section adjacent to cut No. 1, and the section adjacent to cut No. 2. It will be necessary to break some of the material at ends of cuts.

(*f*) Roll remaining two triangular sections out of the roll-in-joints.

(*g*) Pry out lock bars and flanges of the drop-in joints with a small pry bar.

b. Replacement.

(1) *Field access adapter method.*

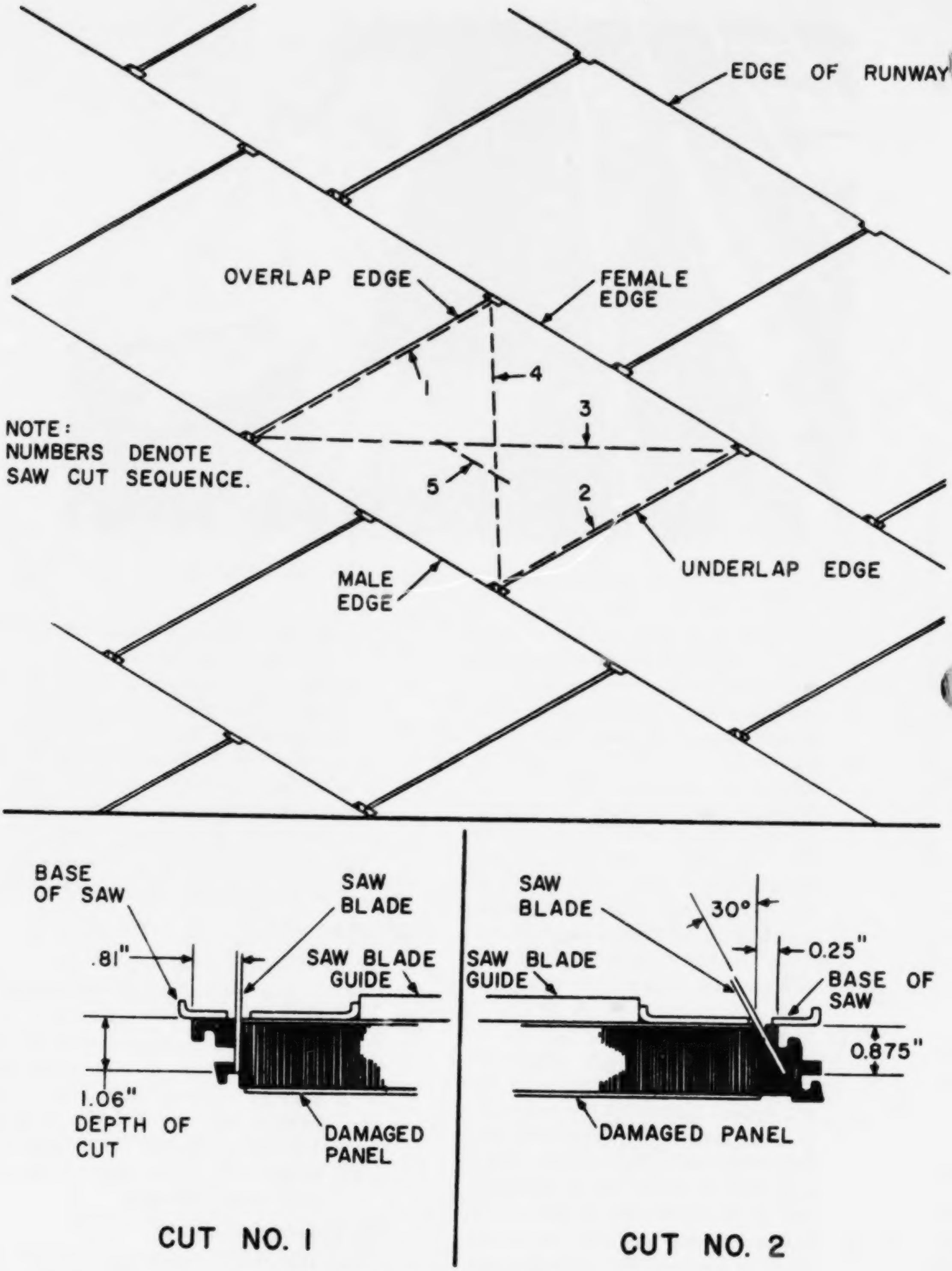
(*a*) Install mats in reverse pattern to that used in removing mats.

(*b*) Install field access adapters in original positions as mat laying progresses. Install key field access adapter at edge of field and install lock bars and lock bar retainers.

(*c*) Install any anchor lugs which may have been removed.

(2) *Repair mat method.*

(*a*) The MX19 repair mat section (fig. 128.12) incorporating the underlap


EDGE OF RUNWAY
OVERLAP EDGE
FEMALE EDGE
4
1
3
NOTE:
NUMBERS DENOTE
SAW CUT SEQUENCE.
5
2
UNDERLAP EDGE
MALE EDGE
BASE OF SAW
SAW BLADE
.81"
SAW BLADE GUIDE
1.06" DEPTH OF CUT
DAMAGED PANEL
SAW BLADE
30°
0.25"
SAW BLADE GUIDE
BASE OF SAW
0.875"
DAMAGED PANEL

CUT NO. 1

CUT NO. 2

Figure 128.11 (Added) *MX19 damaged mat removal.*

edges is installed first. Engage male edge of mat with female edge at edge of opening; lower mat to ground. The side underlap rail of mat will not be engaged. To engage this point, lift adjacent mats 3 inches off the ground with assistance of pry bar and suitable block

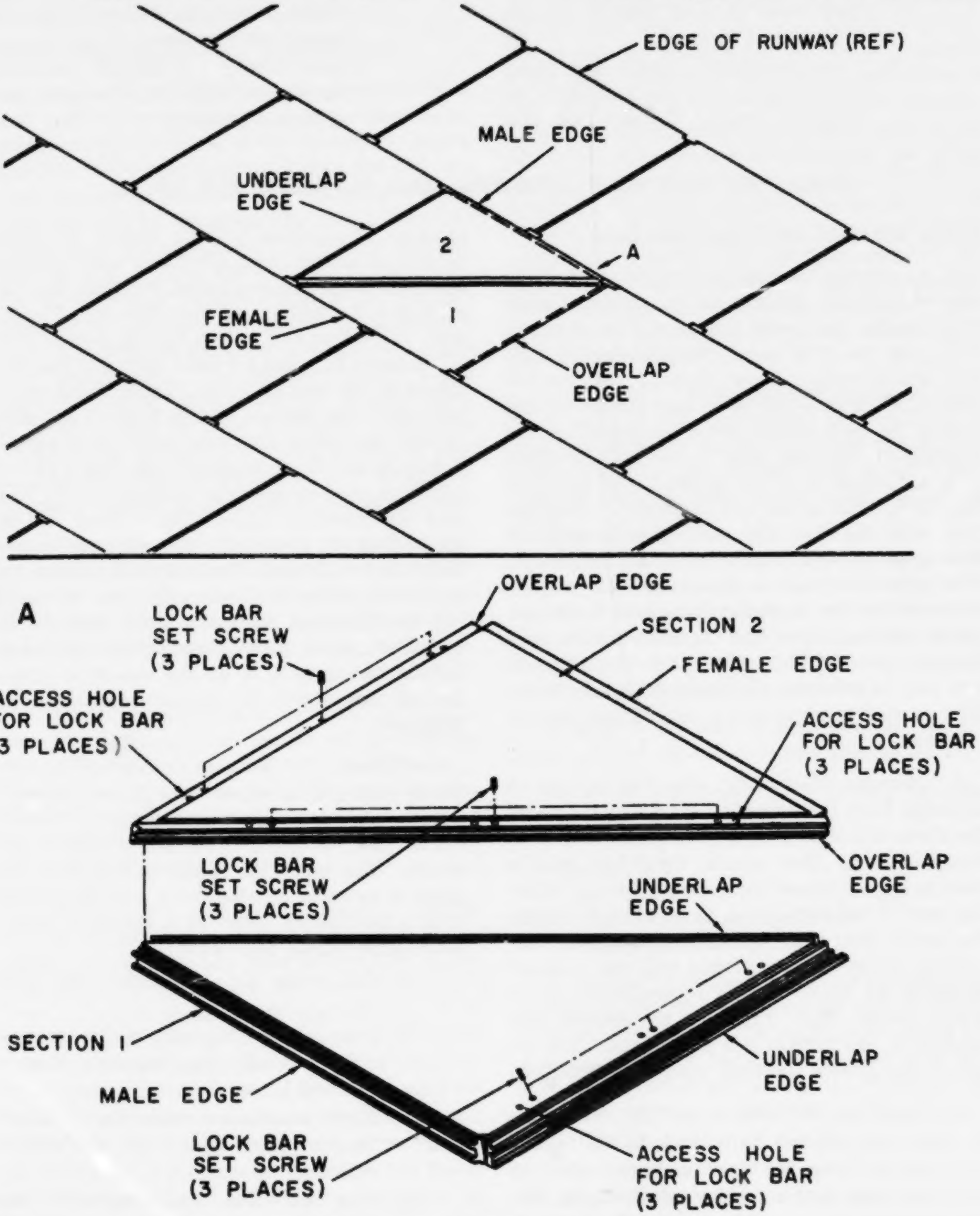

EDGE OF RUNWAY (REF)
MALE EDGE
UNDERLAP EDGE
2
A
1
FEMALE EDGE
OVERLAP EDGE
A
OVERLAP EDGE
LOCK BAR SET SCREW (3 PLACES)
SECTION 2
FEMALE EDGE
ACCESS HOLE FOR LOCK BAR (3 PLACES)
ACCESS HOLE FOR LOCK BAR (3 PLACES)
OVERLAP EDGE
LOCK BAR SET SCREW (3 PLACES)
UNDERLAP EDGE
SECTION 1
UNDERLAP EDGE
MALE EDGE
LOCK BAR SET SCREW (3 PLACES)
ACCESS HOLE FOR LOCK BAR (3 PLACES)

Figure 128.12 (Added) *MX19 repair mat installation detail.*

at corner where the two underlap rails intersect. While adjacent mats are elevated, slide repair mat section under matching overlap rail, then lower adjacent mats to engage drop-in side joint.

(*b*) Install remaining repair mat panel by engaging with drop-in edges on adjacent panels. To lock mat into position, first loosen nine socket-head setscrews one-half turn. Shift lock bars into locked position with aid of pointed end of small pry bar, working through ⅜-inch diameter access holes adjacent to setscrews, then tighten setscrews approximately five turns to hold lock bars in locked position.

Section VII. RECOVERY, CLEANING, AND BUNDLING FOR REUSE

342.4 M6, M8, M8A1, and M9 Mats.

a. Removing. Generally, the panels will be removed in the reverse of the order placed. That is, the last panel placed will be removed first, and the first panel placed removed last. The end-connector bars (hooks) will be unlocked. (The end-connector bars of M8A1 mat should be tack-welded prior to bundling for shipment.) The last panel placed will be raised to a 45° angle with the ground, slid approximately ¾ inch either left or right to aline the hook with the hook slot, and lifted or pried to disengage the side connection, and removed. The adjacent panel in the same run will be removed next by repeating the above directions. As in placing, after two or more panels in a run are removed, the end panel in the adjacent run may be removed. By continuing this procedure, a stairstep pattern is established during removal.

b. Cleaning. Most of the adhering soil can be loosened from the panels by dropping the panel flat from 4 to 6 feet on a hard surface such as concrete or on other panels. Spud bars can be used to loosen the soil by running the bar down the ribs of the panel prior to or after dropping the panel. Soil must be removed from the connecting edges or the panels will not connect properly for reuse. It may be necessary to use water under high pressure to remove soil wedged in the female side connection. The usable clean panels are then ready for bundling.

c. Bundling. M8, M8A1, and M9 mat is repackaged in bundles containing 13 full and 2 half-panels. The M6 mat is repackaged in bundles containing six subbundles. Each subbundle contains four standard and two half-panels. The panels will be nested in pairs, bottom to bottom, with like panel ends together and the connector protected between the box edge and the first rib of the other panel in the pair. (The two half panels will be stacked with a full panel to make a nested pair, and the pair placed in the interior of the bundle). The nested pairs are then stacked on two 2-by4-'s for skids so that the end of alternate pairs are reversed. A bundle will be secured with six flat 1.25—by 0.50-inch steel straps type I, class A or B, Federal Specification QQ–S–781.) Four of the straps will be placed transversely (to encompass the two longitudinal straps) around the short dimension of the bundle, two of which will be 18 inches from the ends with the interior straps equally spaced. The two longitudinal straps will be at the one-third points and all straps will be properly tensioned for shipment.

d. Criteria for Mats to be Reusable. Used panels can be grouped into three separate classes: class 1, reusable as is; class 2, reusable, but in need of minor repair; and class 3, unusable. The essential factor in deciding if a panel is reusable is whether it will fit together with a new panel (used as a standard gage). Acceptable panels may have:

(1) One of the six side-locking lugs missing.

(2) Four of the bayonet hooks missing. (No two adjacent bayonets may be missing.)

(3) Minor cracks not exceeding 1 inch in length (no sharp or protrudling edges).

(4) One of the end-connector bars (hooks) missing. Bent or slightly de-

formed bayonets should not cause a panel to be unusable, as the bayonets can be easily straightened with handtools.

342.5. MX18B, MX18C, and AM2 Mat

a. Removing. Panels can be removed from both ends of the runway at the same time. Also, an entire run can be slid out in several places and two extra crews for each run slid out can start removing panels. The lock bars will be removed first by engaging the hole in the bar with a hook and applying force. Vise-grip pliers may be used to grip the bar and force it out. The panel will be raised, disengaging the end connection. The side connection is hinged out when the panel is raised to about a 45° angle with the ground. The adjacent panel in the same run will be removed next in the same manner. After two or more panels in a run are removed, the end panel in the adjacent run may be removed. By continuing this procedure, a stairstep pattern is established during removal.

b. Cleaning. The connecting and locking features must be free of excessive dirt. Soil will be removed from the panels with a hoe or a square-end shovel. Connecting and locking edges may require washing with water under high pressure.

c. Bundling. Each bundle will contain 11 full and 2 half-panels. The panels will be stacked one on top of the other with the half-panels in the interior of the bundle. The panels will be strapped together to form a compact bundle as described in the bundling procedure for the M8A1 and M8 mats.

d. Criteria for Mat to be Reusable. Panels will be considered reusable if they will fit together at the sides and ends with a new panel. The panel may not have any tears or breaks over 1 inch in length or of such nature as to present a tire hazard. Panels with core failure that are permanently deformed more than 0.5 inch when measured across the transverse direction are considered unserviceable. Panels with weld failures at the ends are considered if the failure is 6 inches or longer or has failed in two places that total 6 inches or more in length.

342.6. MX19 Mat

a. Removing. Panels will be removed from the two outside rows on the runway end where the last panels were placed. The lock-bars will be removed first by engaging the hole in the bar with a hook and applying force. Vise-grip pliers may be used to grip the bar and force it out. The panel will be raised and the overlapping and underlapping edges disengaged. When the panel is at an angle of about 45° the hinge connector will disengage and panel is free to be removed. The adjacent panel in the same row will be removed next in the same manner. After two or more panels in a row are removed, the end panel in the adjacent row may be removed. By continuing this procedure, a stairstep pattern will be established from both sides toward the center row.

b. Cleaning. The connecting and locking features must be free of excessive dirt. Soil will be removed from the panels with a hoe or a square-end shovel. Connecting and locking edges may require washing with water under high pressure.

c. Bundling. Each bundle will contain 32 full panels stacked one on top of the other. The bundle will be strapped tight with four straps, two over each edge. The straps will be spaced at the one-fourth points and over two 2-by-4's used as skids to facilitate handling.

d. Criteria for Mat To Be Reusable. The criteria are the same as those for the AM2 mat.

Page 218, paragraph 347. In line 10, after the word "end" add "and".

Page 219.

349. Placement of the First Panel
(Superseded)

a. Placement of the first section of membrane should be initiated by removing approximately 3 feet of the folded surfacing from the crate and placing it in the anchor ditch that was constructed transversely across the runway (fig. 130). The vehicle should then be driven slowly along the centerline of the runway, with the membrane surfacing being played off the back of the vehicle onto the ground. Care should be taken by the driver of the vehicle to insure that vehicle alinement is maintained with the centerline of the runway. Care should also be exercised by the placing screw to insure that the surfacing is placed in a straight line and flat on the ground, with all slack removed from the surfacing. When the membrane is first placed on the ground, it will consist of an accordion-folded surfacing approximately 50 to 60 inches wide and 100 feet long. After the surfacing has been unloaded from the vehicle, troops should be stationed at equal intervals along the length of the surfacing. Half of the surfacing should be unfolded (fig. 131) to one side of the area and its edge placed in the side anchor ditch. The remaining half of the surfacing should then be unfolded to the other side of the area and its edge placed in the side anchor ditch. After the membrane is alined and positioned, the initial slack is removed from the surfacing.

b. Once the surfacing is positioned on the area and most of the slack removed, steel anchors will be driven through the seams in the surfacing in the end anchor ditch on approximately 9-foot centers and approximately 1 foot from the outside edge of the surfacing (fig. 136.1). Additional slack will then be removed from the surfacing by troops pulling on the free end of the surfacing that has not been placed in anchor ditches. As slack is removed, steel anchors will be driven through every other run of surfacing approximately 1 foot from the outer edge of the free end of the surfacing. Steel anchors will then be driven through the surfacing placed in the side anchor ditches on 15-foot centers and approximately 1 foot from the outer edge of the surfacing. After these anchors are driven, place and compact backfill in the ditches using a motor grader. Compaction may be expedited by using other wheeled vehicles, such as those used to transport membrane surfacing. Terminate the backfilling operation approximately 6 feet from the free end of the surfacing as room will be required to construct the adhesive construction joint.

Page 219.

350. Placement of Succeeding Panels
(Superseded)

a. While the side ditches are being backfilled, the second section of surfacing should be unloaded on the area in the same manner as for the first section. However, the vehicle should be positioned and a sufficient amount of surfacing played off the vehicle so that the end of the second section overlaps the first approximately 24 inches. The surfacing should then be unfolded and the ends placed in the anchor ditches, as was done in the first section. Before any effort is made to remove slack from the second section of surfacing, steel anchors will be driven through the overlapping ends of both sections so that they will be between the anchors driven previously through the first section of surfacing. All anchors will be driven through the overlapping section approximately 1 foot from the edge of the surfacing. After the anchors are driven through the surfacing, initial slack will be removed from the second section of surfacing, and then construction of the adhesive construction joint will be undertaken.

b. Adhesive for this purpose will be supplied in 5-gallon pails.

Note. **Use adhesive G-580-25 for T17 membrane.**

The width of the adhesive joint should be marked on the surfacing with a chalk line or crayon for alinement purposes. To construct the joint, the overlapping section of surfacing will be slit once every 12 feet across the full width of the surfacing. The slit will be made perpendicular to the edge of the surfacing and extend approximately 1 foot from the edge of the surfacing. These slits in the edge of the overlapping surfacing will permit the adhesive construction joint to be made in increments of approximately 12 feet. After the slits are made, the overlapping edge of surfacing will be folded back and adhesive poured from the spout of the pail onto the underlying surfacing. Uniform spreading of the adhesive on the surfacing will be accomplished with the long-handled rollers so that the adhesive covers an area that extends 1 foot beyond the slit in the surfacing (fig. 133). Ample time (usually 2 to 5 min) will be allowed for the adhesive to become tacky to the touch; however, additional or less time may be required depending on weather conditions. Joints will not be constructed during inclement weather, as the adhesive will ball up and not adhere to wet membrane surfacing. When the adhesive becomes tacky the overlapping ends of the sections will be placed in contact and the joint allowed to set for 10 to 15 minutes. Then the joint will be rolled with a rubber-tired vehicle (jeep) to remove air pockets and excess adehsive from the joint. To reinforce the adhesive construction joint, a 36-inch-wide strip of membrane will be placed over the joint and bonded to the surfacing with adhesive (fig. 133.1). In placing the strip over the joint the roll of membrane will be alined so that it straddles the edge of the overlapping section. Adhesive will be spread 10 to 12 feet along the joint at a width of approximately 38 inches. After the adhesive becomes tacky the roll of membrane will be rolled across the adhesive-covered area, maintaining alinement of the strip, and removing all slack and wrinkles from the membrane. This procedure of applying adhesive and then rolling the roll of membrane across the area will be continued for the full length of the joint. After the strip has been allowed to set for approximately 15 minutes, the strip will be rolled with a rubber-tired vehicle (jeep). After constructing the adhesive lap joint, slack will be removed from the surfacing by troops pulling on the free end of the surfacing and then by driving steel anchors through every other 54-inch-wide run of membrane approximately 1 foot from the end of the section. Placement of additional sections of surfacing will be accomplished in the same manner as that described previously.

Caution: **If the motor grader is used to compact the backfill placed in the anchor ditches, care will be taken to prevent the grader blade from snagging or cutting the surfacing.**

When placement of the surfacing is complete, a white, broken centerline will be painted on the surfacing and solid lines painted on the edges of the surfacing near the anchor ditches. Lines approximately 9 inches wide can be painted on the surfacing with the long-handled rollers.

c. A nonskid compound must be applied to those membranes which do not have a pebble-grained skid resistant surface. Nonskid compound consists of a catalyzed epoxy binder with abrasive particles which is applied directly to the membrane with long-handled rollers (fig. 133.2). The green-colored compound is supplied in compartmented 5¼-gallon pails, with the abrasive in the lower compartment and the catalyst and epoxy binder in the upper compartment. Each pail of compound weighs approximately 65 pounds and has a volume of 1.2 cubic feet. The pail should be stirred vigorously with shovels or wooden paddles to mix the

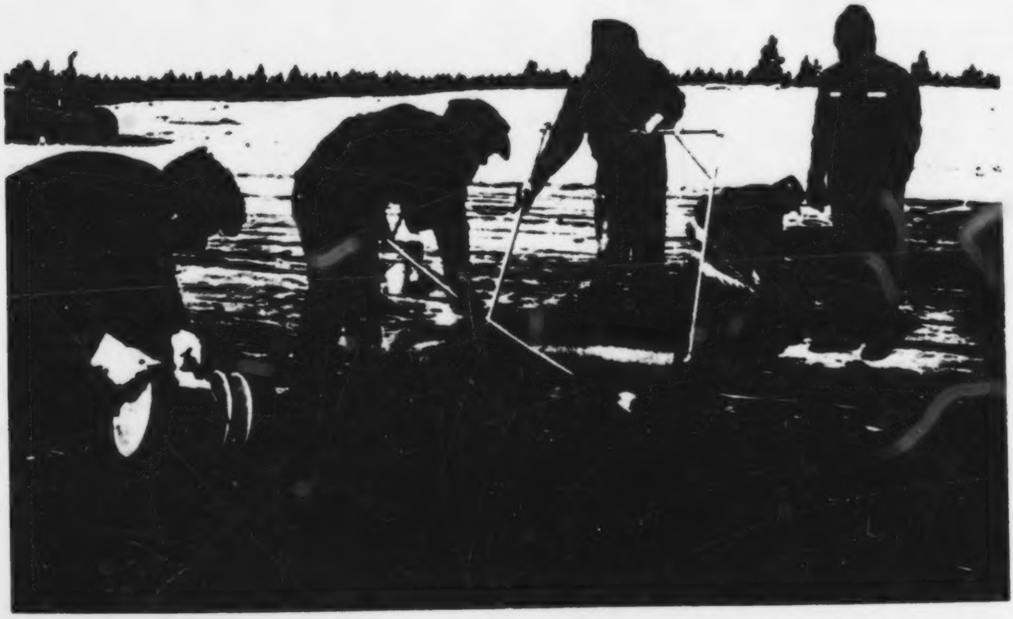


Figure 133.1 (Added) *Reinforcing adhesive construction joint with 36-inch wide strip of membrane.*

catalyst, binder, and abrasive; then the mixture should be allowed to stand approximately 45 minutes before it is applied to the surfacing. After lines are painted on the surfacing the nonskid compound will be applied to the surfacing, taking care not to roll the nonskid compound over the previously painted lines. On areas used as runways, nonskid compound is not applied to areas where short radius aircraft turns are likely to occur. Short turn areas occur primarily at the ends of the runway and at points where taxiways join the runway. Aircraft wheels stick too tightly to the surface and tear the membrane when turning on short radius, particularly when one wheel is locked. The nonskid compound is applied across the width of the runway stopping approximately 5 feet from the edge of the surfacing. For areas surfaced as adjoining taxiways, application of the compound is the same as for the runway, except the width of surfacing on taxiways is governed by the maximum spacing of the main gear of the aircraft operating on the surfacing. The minimum numbers of personnel required to apply the nonskid compound are as follows:

Crew	No. of personnel
Opening pails and mixing nonskid compound.	8
Pouring nonskid compound on surfacing.	4
Rolling and spreading nonskid compound on surfacing.	12

Page 222.

351. Anchorage
(Superseded)

Anchorage methods are broken down into two groups: perimeter and interior.

a. Perimeter Anchorage. Anchorage around the edge (perimeter) of the landing strip is best obtained by L-ditches (fig. 135). The depth of the L-type ditches should be at least 2.5 feet and preferably 3 or more feet. The ditches are constructed in the same manner as drainage

Figure 133.2 (Added) *Application of nonskid compound to membrane surface.*

ditches except that the inside, not the outside, slope is the steepest. All spoil must be moved to the outside of the ditch. The membrane is placed in the ditch with the edge in the bottom of the ditch. It is not extended up the outside bank of the ditch.

Note. Extending the membrane up the far side of the ditch causes surface runoff to be retained in the back-filled ditch.

Steel anchors (fig. 136.1) are then driven through the surfacing approximately 1 foot from the outer edge of the surfacing. After the steel anchors are driven the ditch is backfilled and compacted to the original grade line.

b. Interior Anchorage. Interior anchors are placed along overlap joints where the double thickness of membrane reduces the tendency for the membrane to tear. Overlap at interior joints should be 2.0 to 3.0 feet where anchors are placed. The anchors are constructed as shown in figure 136. They should be thoroughly inspected for burs and warped heads before using. The anchors are then driven through the bottom layer of membrane about 2.0 feet back from the edge (fig. 137) taking care not to warp the head while driving. When the anchors are completely driven into the ground, the adhesive is applied and the top layer folded across the joint as in a standard joint.

Page 266.

354. Holes

(Superseded)

a. Holes and punctures are a serious problem with membranes as they allow water to enter the subgrade and may cause ballooning (fig. 138). Usually, ballooning occurs only when the surfacing has been punctured or torn and air is forced through these openings in the surfacing by the prop wash of aircraft engines. The air forced through the openings and subsequently trapped beneath the surfacing causes the surfacing balloon, arise from the surface of the ground, and become airborne. Service tests on the surfacing have shown that aircraft may operate over small surface failures for a limited period without severe damage or ballooning the the surface; nevertheless, the best practice is to *repair all failed areas as soon as possible*. Less time and effort will be required to repair a small area immediately after failure

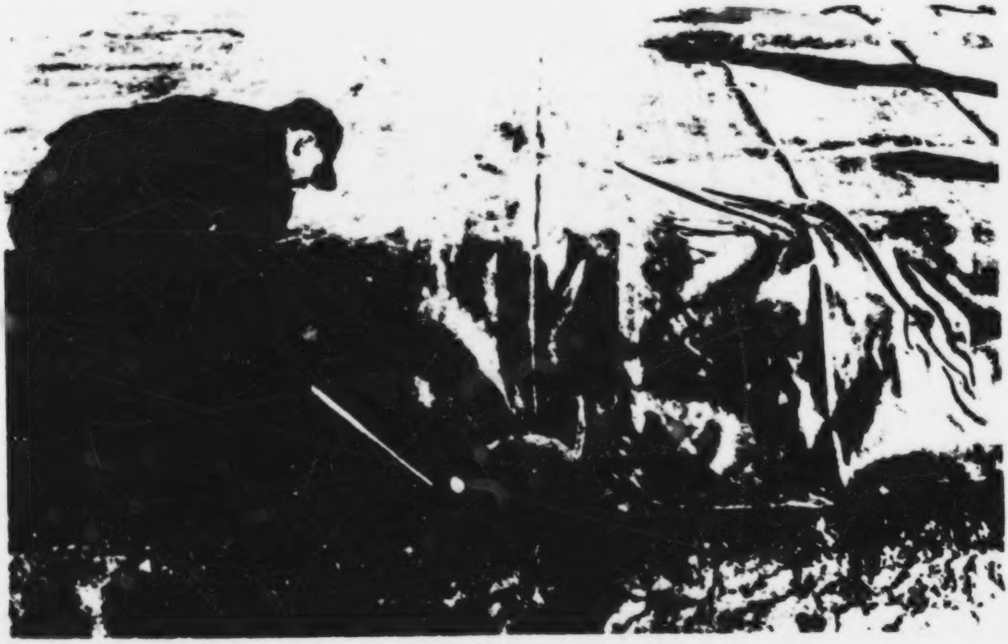


Figure 136.1 (Added) *Driving anchor through surfacing into end anchor ditch.*

than to risk the small area developing into a major repair problem.

b. The method of patching holes is the same regardless of whether or not nonskid compound has been applied to the surface. Failed areas of the surfacing will be repaired by slitting the failed surfacing in the form of a cross and folding the four flaps back. Then adequate membrane surfacing will be removed from a roll of membrane and placed beneath the nonskid-coated membrane surfacing so that it extends beyond the failed area of surfacing approximately 2 feet on all sides. Adhesive will then be applied to the top of the membrane removed from the membrane roll and to the bottom of the surfacing coated with nonskid compound. Adhesive will be spread over the membrane with the long-handled rollers. After the adhesive becomes tacky (2 to 5 min) the flaps that were folded back previously will be placed in their original positions, and the adhesive allowed to set for approximately 15 minutes before rolling the patched areas with a jeep. The size of the repair and maintenance crew will be determined by the size of the area surfaced. For airfield complexes, the crew will be four to six men.

Page 226.

355. Recovery

(Superseded)

a. Introduction. Membranes may be recovered for future use by two methods: deliberate and hasty. No special skill is required for recovery of membrane surfacing. Engineer troops should be used if available; but if not, any troops in the field army can recover the membrane. Recovery by the deliberate method is accomplished in the reverse order in which the membrane was placed; that is, the ditches are first dug out, taking care not to cut the membrane. The field joints are cut, and the membrane is refolded and crated. With careful supervision, more than 90 percent of the usable membrane can be recovered. The hasty recovery is identical to the deliberate recovery, except that the membrane is cut at the edges and the portions in the anchor ditches are left in place. The hasty method is faster and requires less supervision, but the width and length of the membrane are shortened by the amount left in the anchor ditches. The shortened membrane can be reused on another field with narrower runway requirements or as a taxiway or warmup apron surfacing.

b. Personnel and Equipment.

(1) *Personnel.* The number of troops and equipment available will govern the recovery rate. In previous recovery operations, the crew composition found to produce optimum recovery rate was as follows:

		NCO	*Other EM*
Supervisor	Overall coordination and supervision of effort.	1	
Grader guide	Guide grader during opening up of anchor ditches.	--	1
Tack anchor crew	Clean mud from membrane; pull tack anchors and pull membrane edges from ditch; cut off cover strips as required and pull out joint tack anchors.	1	10
Panel drying crew	Cut panels free at joints; spread wet membrane to dry.	1	15
Patching crew	Patch membrane panels.	1	3
Panel folding crew	Fold panels lengthwise.	3	10
Palletizing crew	Fold panels onto pallets.	2	8
Banding crew	Band panels on pallets.	--	2
Crating Crew	Collect pallets and place in central location; secure folded surfacing on pallet with steel straps and bolt on tops; stencil crates.	2	8
	Totals	11	57

(2) *Equipment.* The equipment and tools required to recover the surfacing are as follows:

Open anchor ditches	*Motor grader
Clean mud from membrane and remove water from anchor ditches should rain occur.	Air compressor with sump pump

Remove tack anchors and membrane from anchor ditches.	Picks, shovels, crowbars, chain, cable, vehicle
Cut surfacing free at joints.	Knives
Collect folded surfacing and pallets in a central location.	*Rough terrain forklift 5-ton wrecker
Fold panels onto pallets.	*Rough terrain forklift, 5-ton wrecker
Band folded surfacing on pallets.	*Steel strap banding machine

*These items are not authorized an engineer combat company (TOE 5-37).

c. Procedures for Recovery of Surfacing. Recovery is initiated with the removal of backfill from anchor ditches with a motor grader (fig. 138.1). Care should be exercised to prevent the grader blade from snagging or cutting the surfacing (fig. 138.2). Since the membrane should be cleaned and dried before reuse, any pools of water and earth should be swept off the surfacing. The tack anchors should be removed as follows:

(1) *Side and end anchor ditches.* Use a 60-inch crowbar or railroad picks to pry up the heads of the anchors. If the ground is wet, they can be removed by using two long-handled shovels (fig. 138.3).

(2) *Construction joints.* Cut the surfacing with knives on both sides of the 36-inch-wide reinforcing strip of membrane (fig. 138.4) and pull up on the center of the strip with a rough terrain forklift (fig. 138.5). When the strip is removed with the forklift, the anchors will come up with the membrane. If the forklift is not available, the anchors may be removed by prying up the head of the anchor and placing

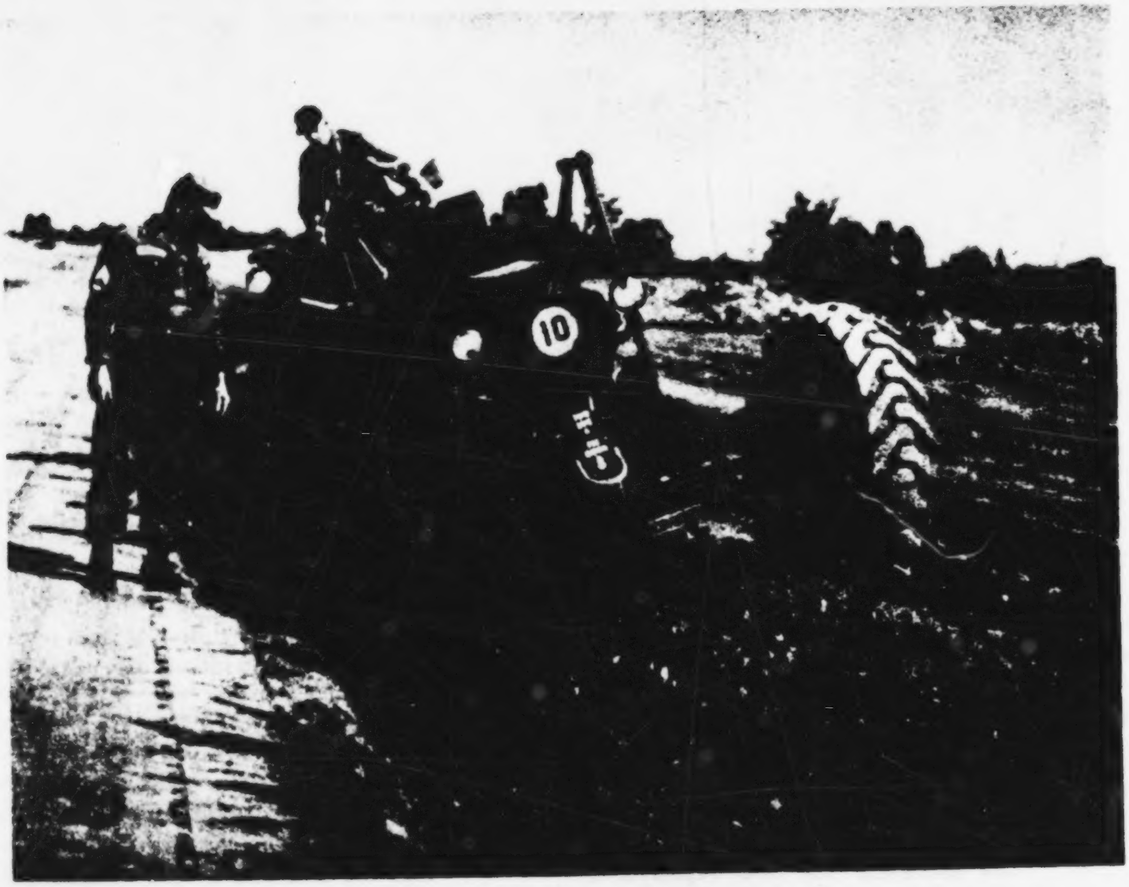


Figure 138.1 (Added) *Opening anchor ditch using grader.*

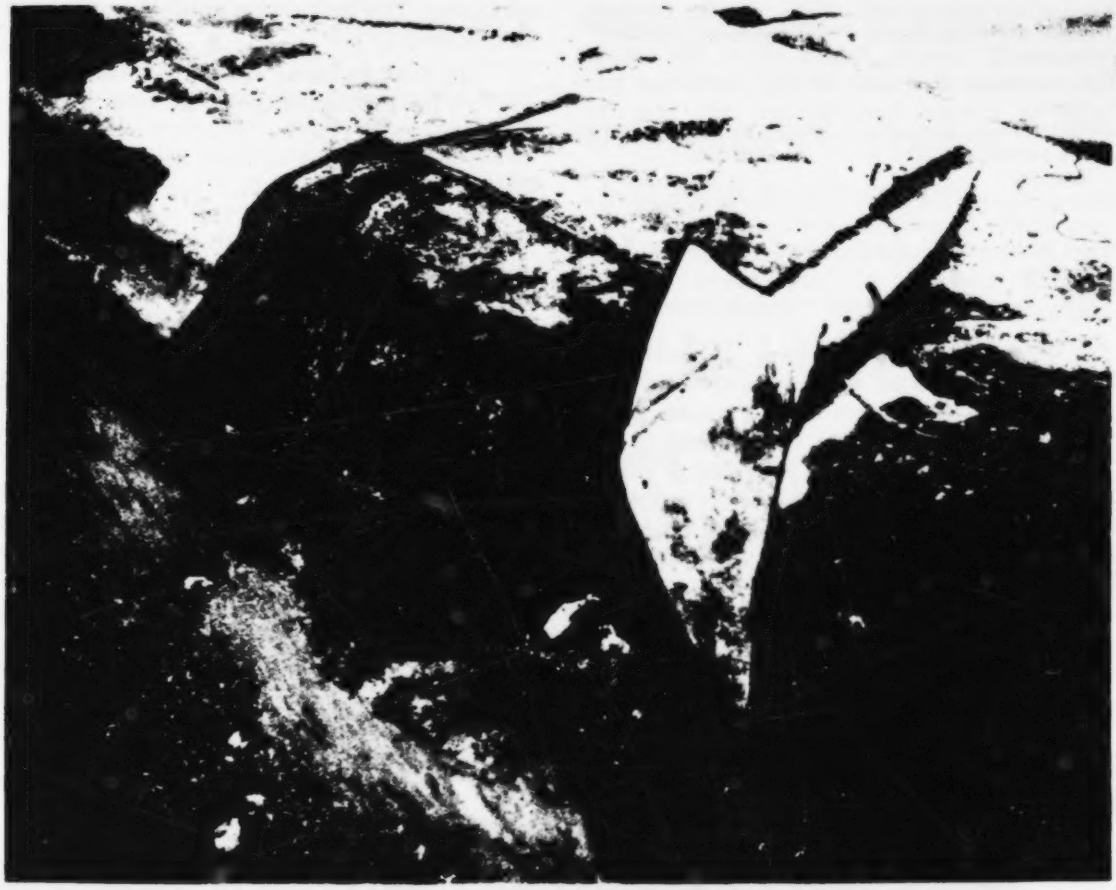


Figure 138.2 (Added) *Tear caused by grader opening anchor ditch.*

a chain or cable beneath the head and around the anchor shaft. Then the anchors can be removed by truck (fig. 138.6).

(3) *Repair and folding of surfacing.* Before the surfacing is folded, tears or punctures that exist in the surfacing should be repaired. Repairs should be made by precutting patches of the membrane to size and applying adhesive to the patches and area to be repaired. Patches should be placed on both sides of the surfacing. Detailed procedures for use of the adhesive are contained in paragraph 350*b*. After the surfacing has been repaired, it should be accordion-folded lengthwise into a width approximately 3 inches narrower than the wooden pallet (fig. 138.7). To start placement of the folded membrane onto the pallet, a pallet should be placed on the forks of the forklift. Then one of the tree ends of the folded surfacing should be lifted so that the forklift can move the pallet beneath the surfacing for the full length of the pallet. For folding the surfacing onto the pallet, a minimum of two NCO's and eight men with two 2-inch-diameter by 10-foot-long pipes should be used. After the forklift has moved the pallet beneath the surfacing, the free end of the surfacing is held in place by the foot of one of the

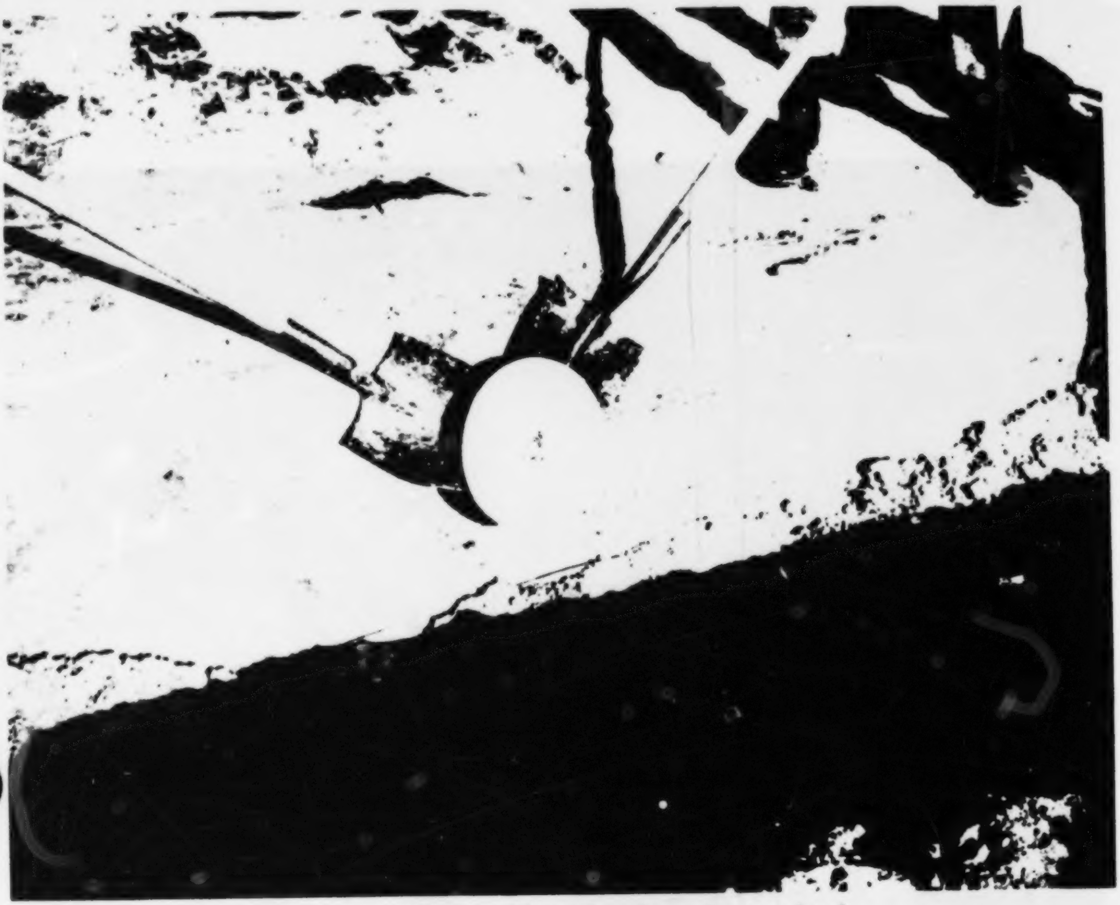


Figure 138.3 (Added) *Pulling tack anchors using two shovels.*

NCO's, and the other NCO at the other end of the pallet places his foot on the surfacing where he wants the fold in the surfacing to occur. The eight men, four to each pipe, will support a length of the surfacing equal to that of the pallet so that the forklift can move forward and cause the surfacing to fold on the pallet. When the forklift has moved forward two pallet lengths so that the supported length of the surfacing is folded back at the pallet edge, the supported membrane is lowered to the pallet, the pipes withdrawn, and the folding procedure repeated until the whole section of surfacing has been placed and folded on the pallet (fig. 138.8). The folded surfacing should be secured on the pallet with three steel straps (fig. 138.9). To protect the surfacing during shipment, the top of the wooden crate should be placed over the surfacing and bolted to the pallet with lug screws (fig. 138.10).

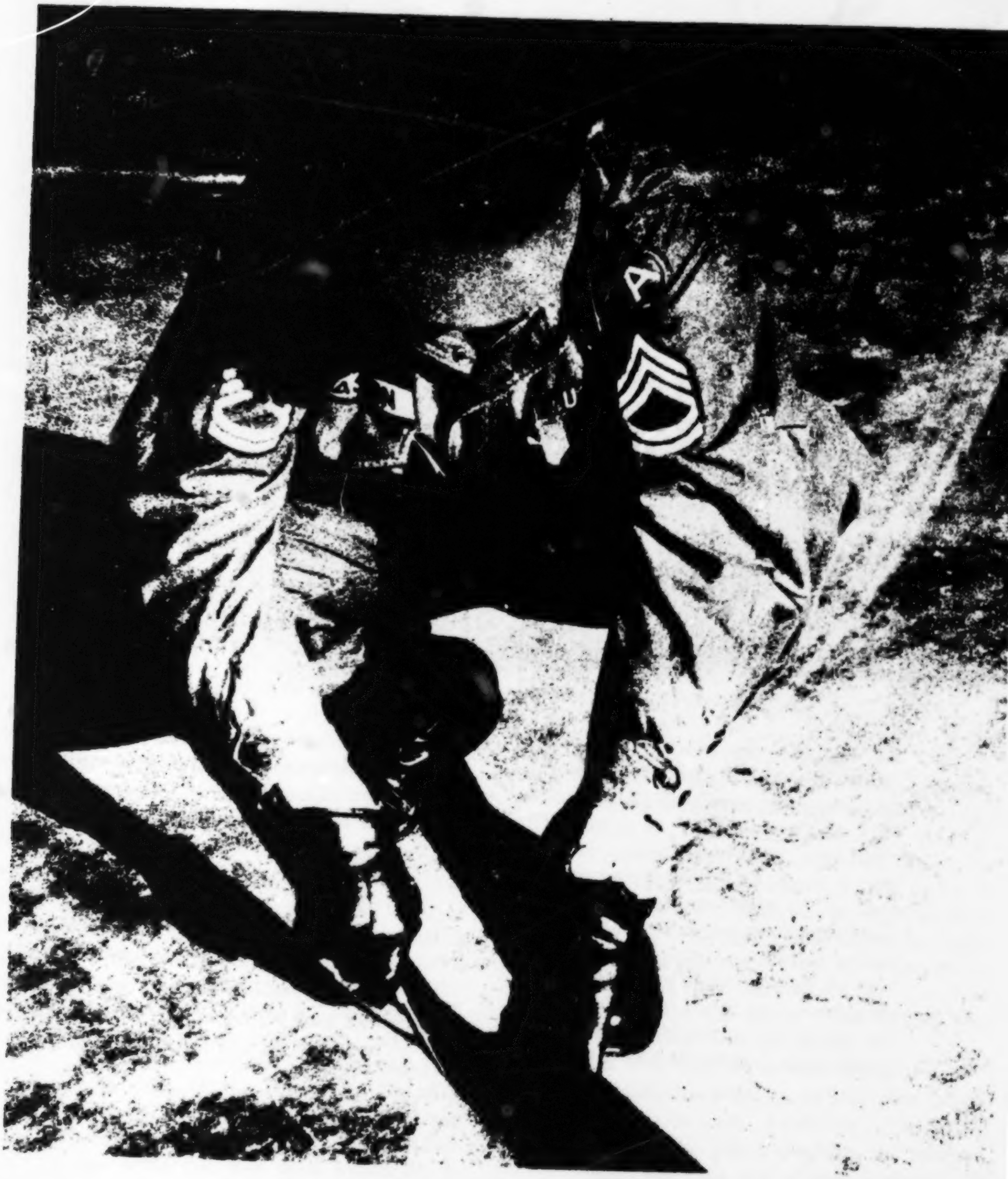


Figure 138.4 (Added) *Cutting panels free at joints.*

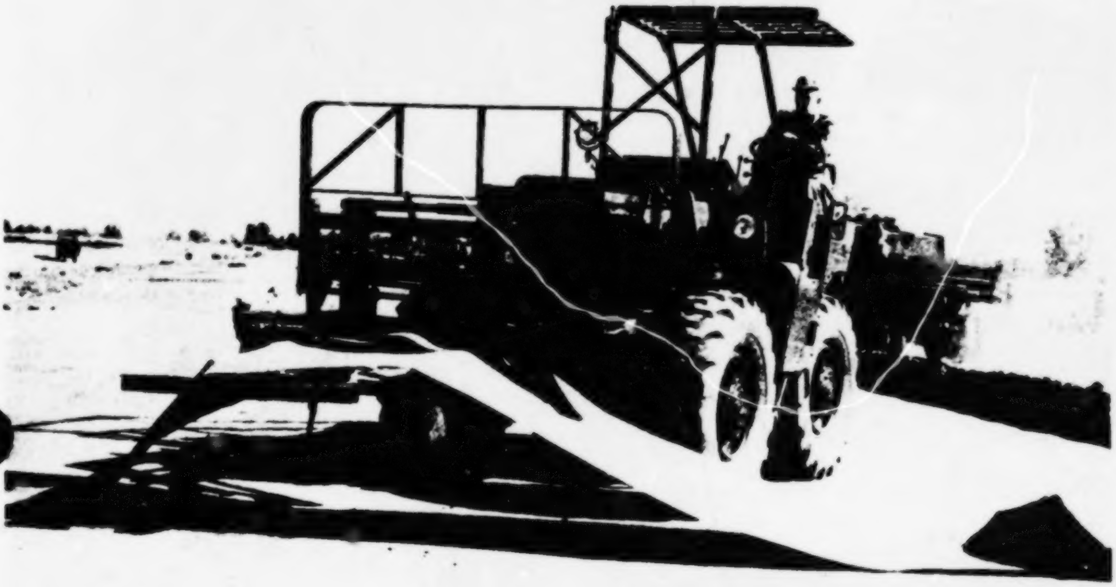


Figure 138.5 (Added) *Removing cover strips and pulling tack anchors using rough terrain forklift.*

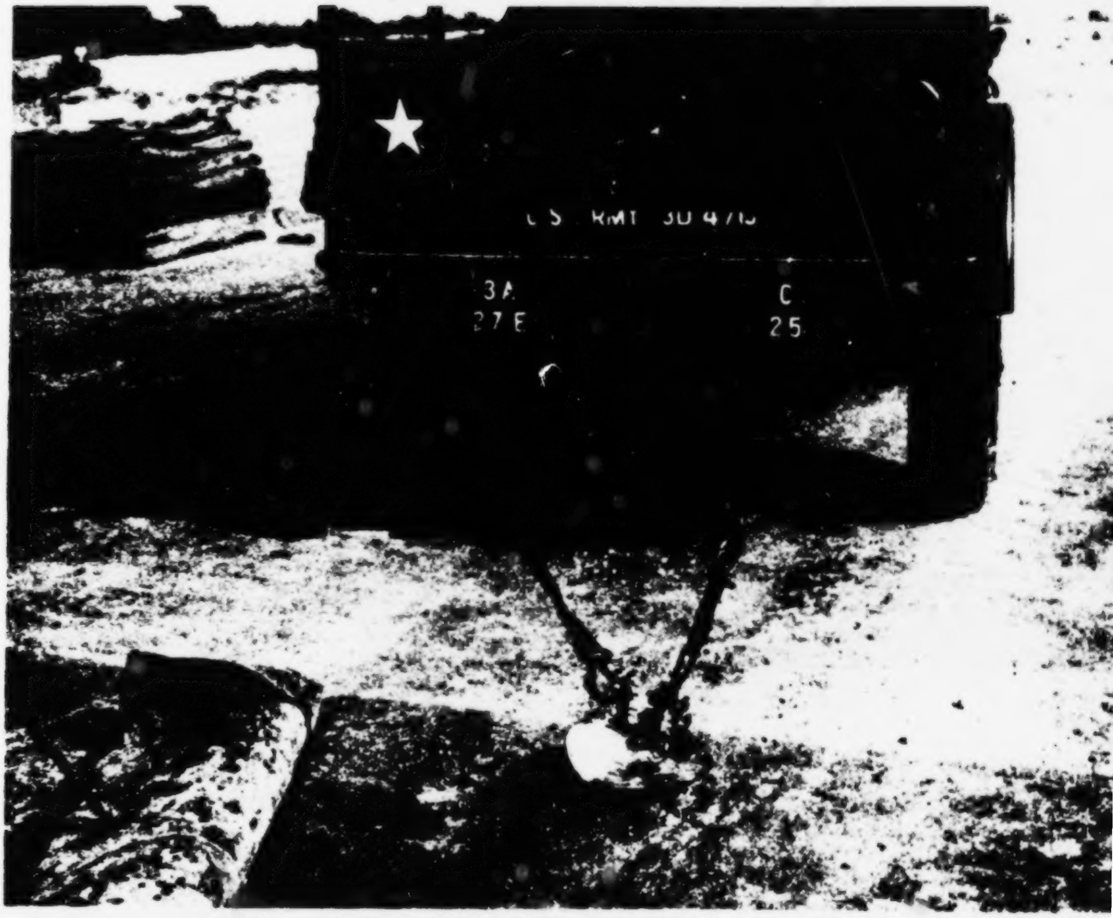


Figure 138.6 (Added) *Pulling anchors using a cable and ¾-ton truck.*

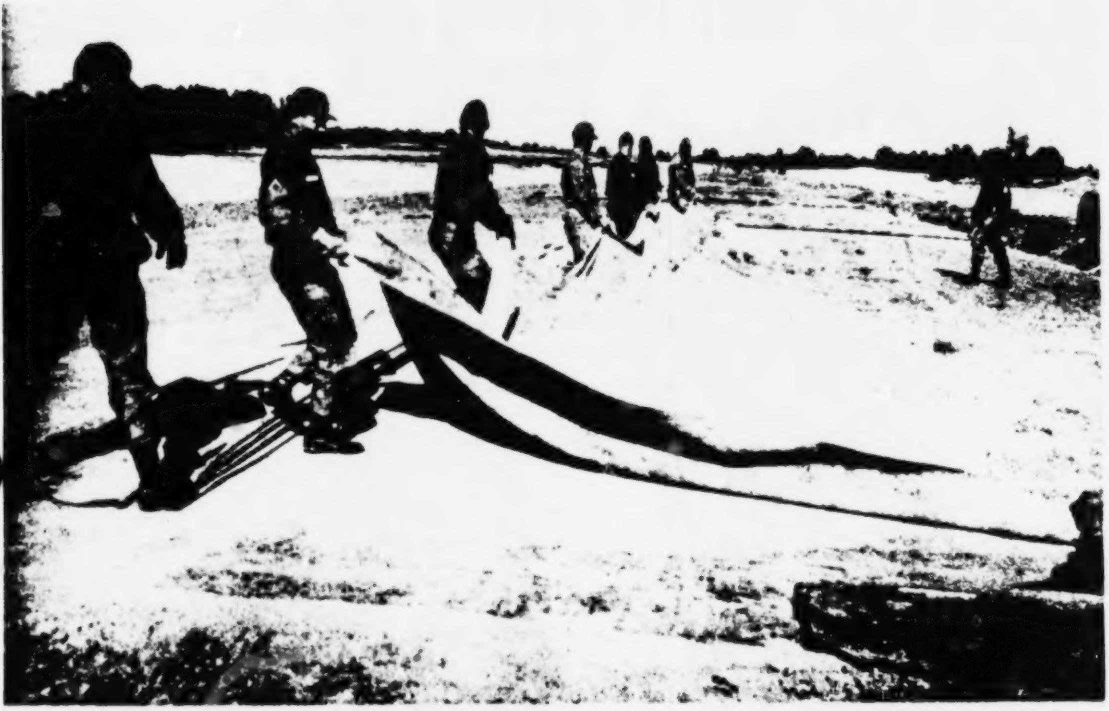


Figure 138.7 (Added) *Folding panel lengthwise.*

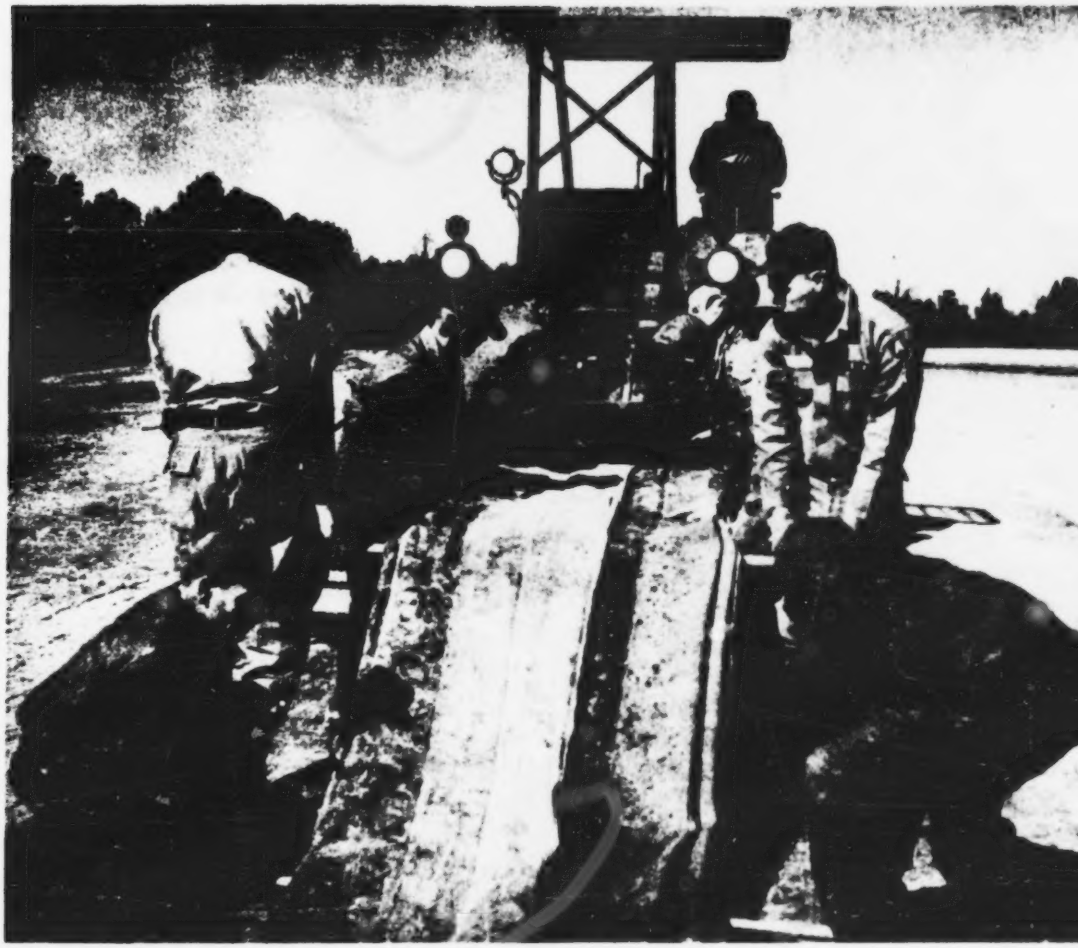


Figure 138.8 (Added) *Folding panel onto pallet.*

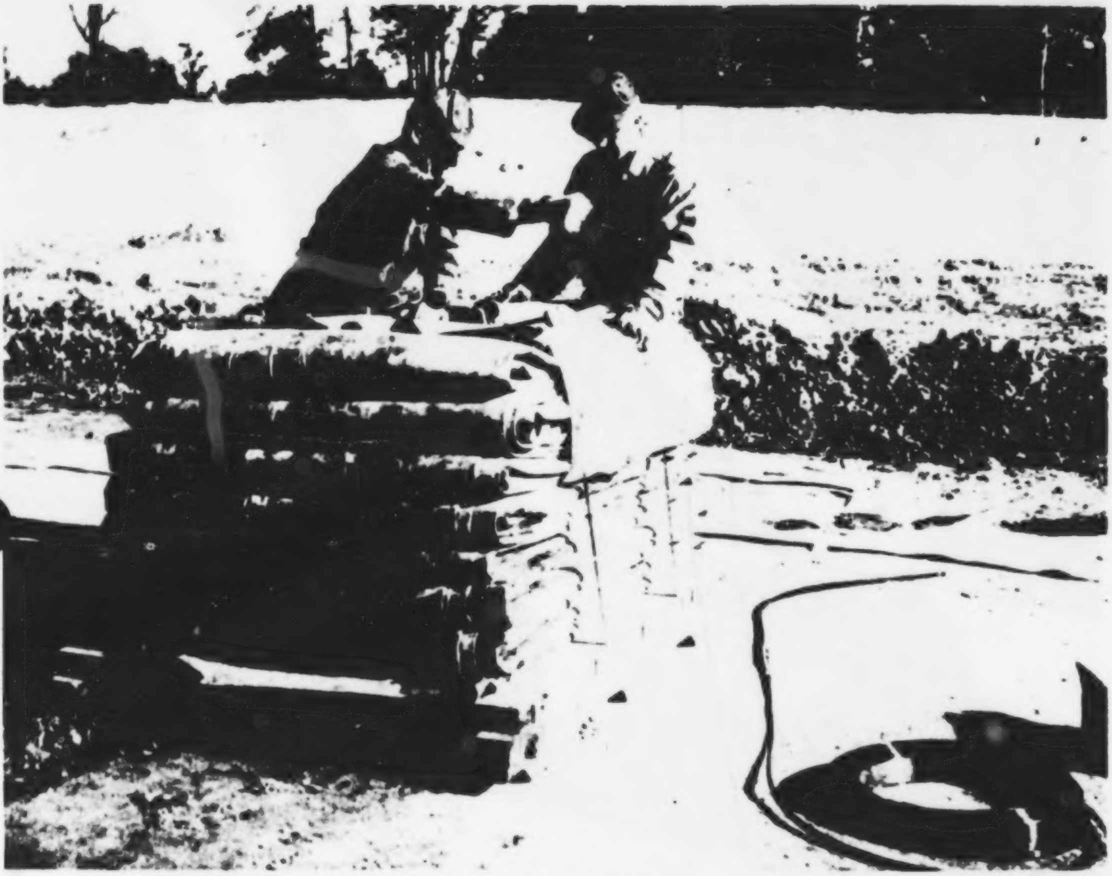


Figure 138.9 (Added) *Banding panel on pallet.*

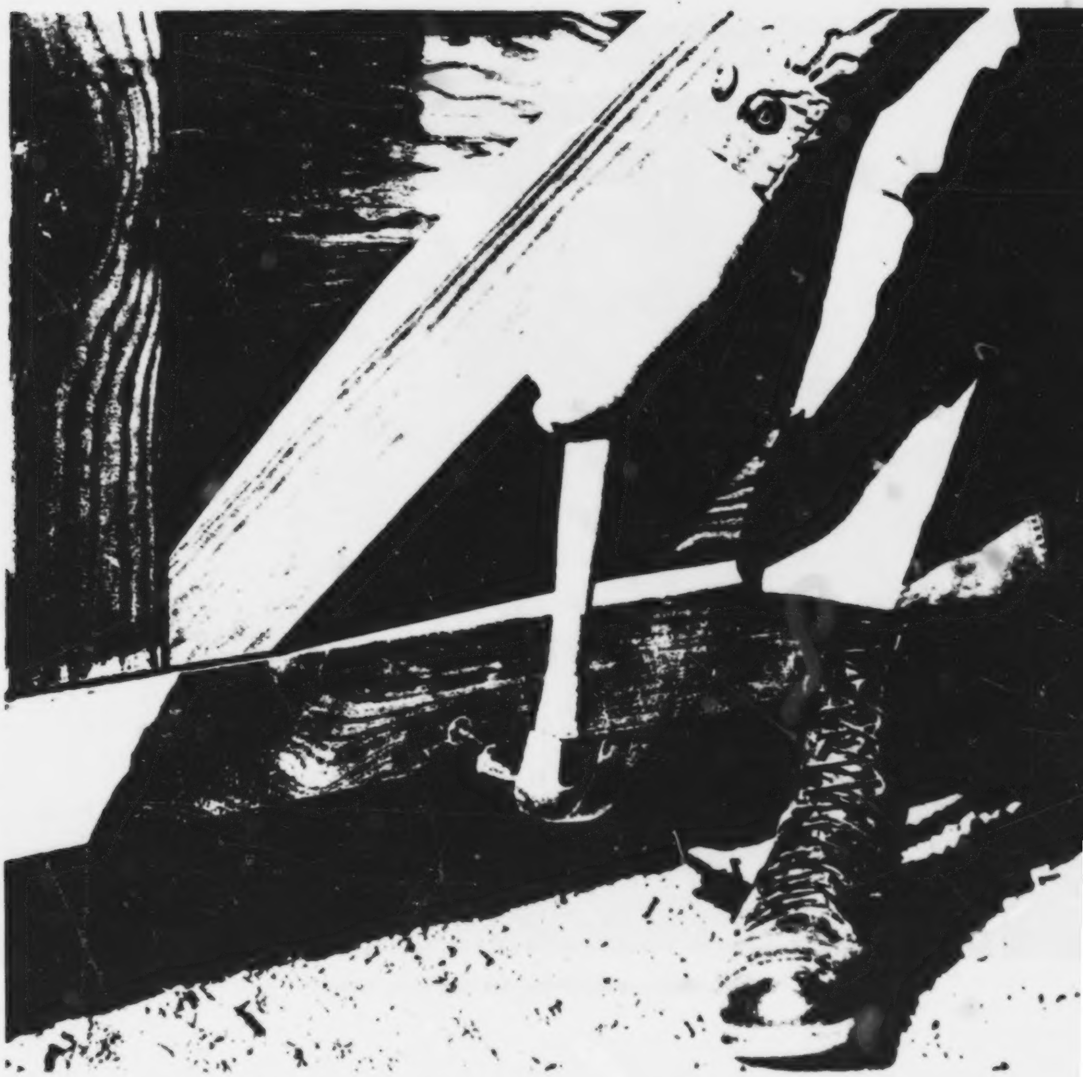


Figure 138.10 (Added) *Bolting on top of membrane crate.*

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NG: State AG (3).

USAR: Same as active Army except allowance is one copy to each unit.

For explanation of abbreviations used, see AR 320-50.

* TM 5-337

TECHNICAL MANUAL }
No. 5-337 }

HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, D.C., *21 February 1966*

PAVING AND SURFACE OPERATIONS

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* This manual supersedes TM 5-337, 12 July 1960.

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PART ONE

BASIC CONSIDERATIONS

CHAPTER 1

INTRODUCTION

1. Purpose and Scope

a. This manual provides information and guidance for personnel engaged in, or responsible for, bituminous, concrete, and expedient surfacing operations for roads and airfields. It includes information on construction materials, mix design, equipment, production, placement, and repair of concrete pavements and bituminous pavements and surfaces. Also covered are field expedient materials and methods for hasty surfacing of roads and airfields. The recommended methods for asphalt plant layouts are shown in TM 5–337–1.

b. Surfaces as discussed in this manual are limited to those which are capable of withstanding wheeled or rubber-padded tracked loads and are of a higher order than a base.

c. The material presented herein is applicable to both nuclear and nonnuclear warfare.

2. Comments

Users of this manual are encouraged to submit recommended changes or comments to improve the manual. Comments should be keyed to the specific page, paragraph, and line of the text in which the change is recommended. Reasons should be provided for each comment to insure understanding and complete evaluation. Comments should be forwarded directly to the Commandant, U. S. Army Engineer School, Fort Belvoir, Va. 22060.

3. Concept of Military Construction

The advent of devastating weapons and increased mobility of modern warfare may suddenly create combat conditions in any area. In such event, construction of roads and airfields must proceed even against tremendous difficulties. Durability of construction and other standards may require modification on the basis of the immediate tactical or strategic situation, as well as on such factors as urgency, availability of men, materials, and equipment, and continuous enemy attack. An understanding of the principles of construction will aid engineer troops to attain the best construction possible with any materials that may be available.

4. Stage Construction

Stage construction is the planned expansion of a road either in width or depth. It allows roads to be upgraded to increasing requirements with a minimum outlay of time, men, and materials. Construction materials should be selected with future improvements in mind.

a. *Depth*. Stage construction in depth is a vital consideration in planning combat zone roads. Flexible pavements lend themselves most readily to this task. A typical military application of stage construction in depth would be the original construction of an unsurfaced road in the combat zone. As the area of combat moves further forward, traffic capacity can be increased by surfacing with a road-mix pavement. Later, when the road is in a rear area, this road would receive either a final paving of hot or cold plant mix, if durability increase is necessary, or a surface treatment, if increased surface smoothness is needed. This road is now capable of the high volume and heavy loads of rear area traffic, assuming the base and subbase are adequate. Caution should be taken to insure that all layers are completely bonded together so that strength increases may be realised.

b. Width. As the loads or density of traffic increase, it may be found that the road is too narrow to serve its purpose; thus, stage construction in width is necessary. Planning for this widening should have been made during the original construction. Cuts and fills should have been made wide enough to leave room for the additional width. Most military widening operations will be less than one lane in width.

5. Safety

Safety precautions must be rigidly observed
paving operations, particularly in the use of i
flammables. Paragraph 142 calls particular atte
tion to the proper safety procedures for the heati
of bitumens. Paragraph 56 deals with proper tra
maintenance procedures. Safety precautions will
noted at other pertinent points throughout the te

CHAPTER 2

TYPES OF PAVEMENTS AND SURFACES

6. Introduction

Discussion in this manual is limited to three types of paving and surfacing operations: bituminous, portland cement concrete, and expedient operations. The term "concrete" as used herein means portland cement concrete unless otherwise specified. Selection of the types of pavements and surfaces is based on traffic conditions, availability of equipment, men and materials, time allotted, climatic and weather conditions, expected subgrade deformations, and design life. The end results of operations which contribute to the overall load-bearing capacity of the structure are called pavements. Bituminous pavements are usually greater than 1 inch thick. Con- ete pavements are usually more than 6 inches ick. The reason for this differential in thickness is discussed below. Bituminous surface treatments and membranes do not contribute to the load-bearing capacity of the base and are usually less than 1 inch thick. The function of a surface is to retain and waterproof the load-bearing courses.

7. Rigid and Flexible Pavements

There are two different types of pavements which contribute to the bearing capacity of the base. These pavements are either flexible or rigid. Flexible pavements give or flex under loading. Ideally, the load is distributed over a surface area proportional to the distance of the area from the surface. Rigid pavements, such as concrete, will deflect slightly under a design load and distribute this loading over a larger area, even bridging small weak spots in the base. Figure 1 shows the difference between the load distributions of rigid and flexible pavements.

8. Bituminous Surfaces and Pavements

a. Components. Bituminous surfaces and pavements are composed of compacted aggregate and bitumen. The aggregate performs three functions. transmits the load from the surface to the base course, takes the abrasive wear of the traffic, and provides a nonskid surface. The bituminous binder (bitumen) holds the aggregate together, preventing displacement and loss of aggregate, and provides a waterproof cover for the base.

b. Advantages of Bituminous Surfacing. Bituminous surfaces are particularly adaptable to stage construction. Additional courses can be added to existing pavements to provide further reinforcement if the loads or density of traffic increases. The flexibility of bituminous wearing surfaces permits slight adjustments caused by settlement of the subgrade without detrimental effect. Bituminous wearing surfaces provide a resilient, waterproof medium that protects the base course from water and traffic. Properly designed bituminous wearing surfaces, when compared with concrete, are less affected by temperature strains. Bituminous surfaces resist wear, weathering, and deterioration from aging with only nominal maintenance. While it is true that bituminous materials are highly versatile, and serve admirably in temporary, expedient, and light traffic situations (where concrete is not justifiable), it is equally true that thicker bituminous pavement designed for heavy and continuing duty are fully comparable to concrete designed for the same service, consisting of heavy volumes of traffic or heavy wheel loads. This is true not only for highways, roads, and streets, but also for airfields.

c. Limitations of Bituminous Surfacing. Bituminous wearing surfaces lack appreciable beam action to carry wheel loads over weak spots in the subbase. For this reason, the subgrade must have an adequate, uniform bearing strength and the base course must have adequate thickness, bearing capacity, and cohesion. Structures containing bitumens oxidize, thus losing their resilience with age. This is a major limitation when a proposed project is to be of a standby nature.

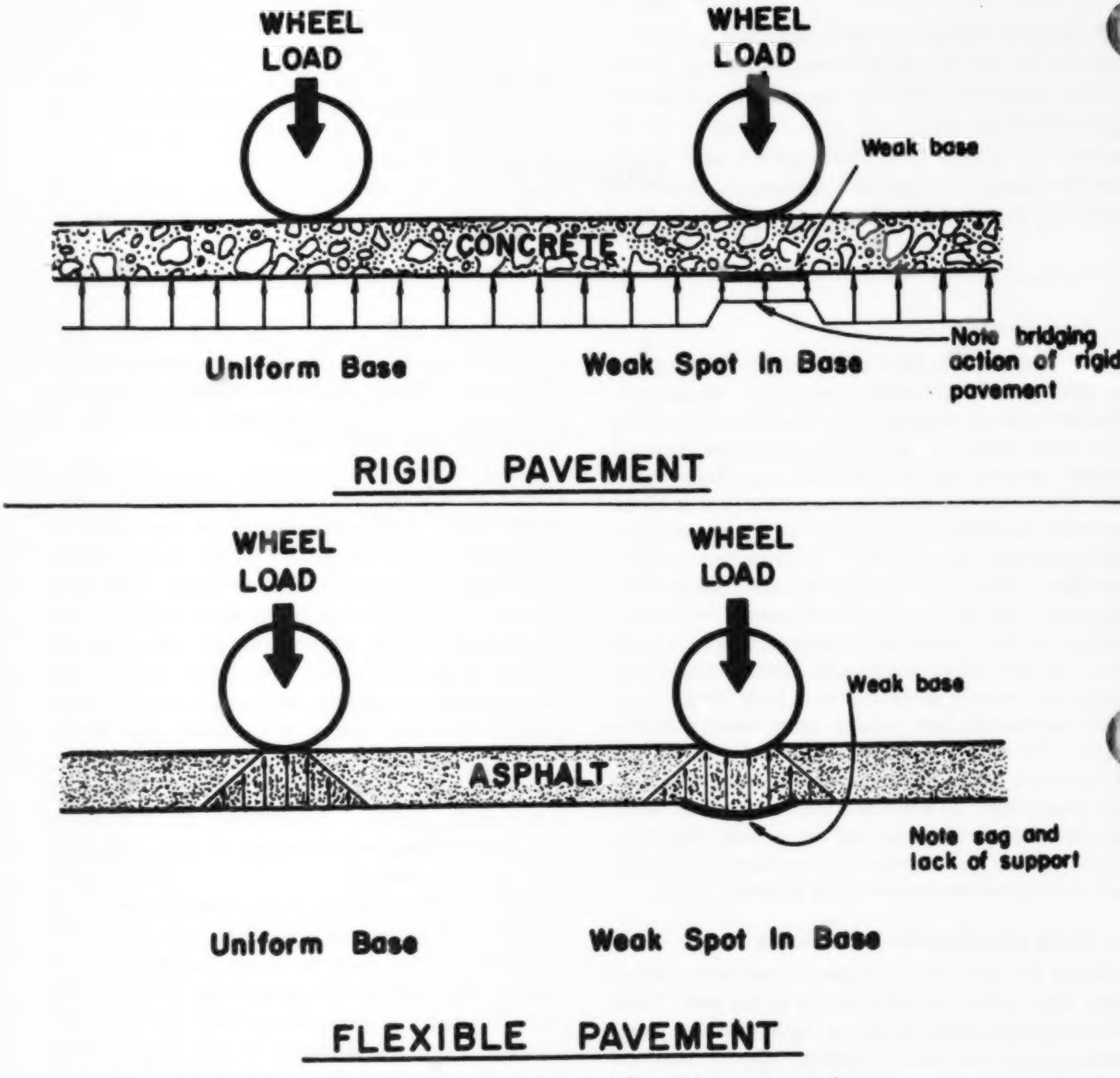

WHEEL LOAD
WHEEL LOAD
Weak base
CONCRETE
Uniform Base
Weak Spot In Base
Note bridging action of rigid pavement
RIGID PAVEMENT
WHEEL LOAD
WHEEL LOAD
Weak base
ASPHALT
Note sag and lack of support
Uniform Base
Weak Spot In Base
FLEXIBLE PAVEMENT

Figure 1. Load distribution of rigid and flexible pavements.

Figure 1. Load distribution of rigid and flexible pavements.

9. Portland Cement Concrete Pavements

a. Concrete pavement is constructed from concrete and, in some cases, wire mesh for temperature and shrinkage crack control. The load-bearing capacity of concrete pavements is distributed by beam action over a wide area. Concrete is essentially an artificial conglomerate stone consisting of a mass of strong inert material in a granular or fragmental form (aggregate) bound together by hardened water-cement paste. The quality of concrete largely depends on the proportions of th ingredients, especially the proportion of water cement, the manner in which the concrete is handl and placed after it is mixed, and the thoroughne of curing. For best results, the careful selection materials and their proper handling, storing, a measuring are also necessary.

b. Concrete is adaptable for paving roads, runways, taxiways, or other surfaces that will carry heavy volumes of traffic or heavy wheel loads. Concrete, however, is not usually used for pavement construction in the theater of operations because the mixing, placing, and curing of concrete usually require more manpower and time than bituminous surfacing operations. Concrete usually is used for more permanent types of construction. An adequate subgrade and base are as important for concrete pavements as for bituminous surfaces. Even though concrete will bridge weak spots in the subgrade, repeated loading will lead to fatigue failures at these points.

10. Expedient Pavements and Surfaces

In a theater of operations, routes of communication are of vital importance for movement of troops and supplies. In the combat area, when men, materials, equipment, or time are not available for more permanent surfacing construction, expedient materials and methods may be used. With a choice of materials or methods, the determining factors in selecting the type of expedient to be used will be the time available for construction, the required permanency, the type of terrain, and the anticipated type of traffic. As an expedient, any method or material that will provide a temporary road or airfield may be used. Expedient pavements and surfaces should be regarded as emergency measures and not as permanent installations. Bituminous surfaces may be used as expedients providing the criteria for establishing suitable bases have been met. The advantage of bituminous materials for expedient construction is the ease of increasing the life and capacity by stage construction in depth. Most prefabricated hasty surfaces have a short life and high maintenance outlay, but the ease and speed of construction greatly outweigh these disadvantages when these surfaces are used as intended. It is not the intention of this manual to limit the engineer to the expedient methods discussed herein, but to present some of the more common methods that may be used. Sound engineering principles and imagination will lead to many improved expedient methods.

PART TWO

BITUMINOUS WEARING SURFACES

CHAPTER 3

BITUMINOUS MATERIALS

Section I. BITUMENS

11. Types of Bitumens

The two types of bituminous materials used in road and airfield construction are asphalt and tar. Tests for the field identification of tar and asphalt paving compounds are given in TM 5–530.

a. Asphalt. Asphalt is a natural or manmade byproduct of petroleum distillation (fig. 2).

(1) *Natural asphalt.* Natural asphalts are found in nature, either as lake (or pit) asphalt or rock asphalt. Lake asphalt is formed when crude oil seeps to the surface of the earth where the lighter fractions (volatile materials) are driven off by the action of sun and wind. Large deposits of lake asphalt exist in Trinidad and Venezuela. Rock asphalt occurs in more than one form. It may be asphalt impregnated in porous rock or it may be asphalt hardened into a rock-like form. Natural asphalts may be used when they are locally available; otherwise manufactured asphalt is usually more desirable.

(2) *Manufactured asphalt.* Manufactured asphalt is more uniform in quality than natural asphalts. Asphalt cement is the residue (waste product) of the distillation of crude oils. It may be used alone or in combination with other materials to form asphalt cutbacks and emulsions. All three of these bituminous compounds are collectively referred to as asphalts.

b. Coal Tar and Water-Gas Tar. Unlike asphalt, tars are extracted from coal. Coal tar produced as a byproduct of coke production and water-gas distilled from tar vapors produced, condensed, and collected during the production of illuminating gas are both used in paving tars. Water-gas tar is usually combined with coal-gas tar as a flux. The two types of paving tars are road tars and road tar cutbacks. Figure 3 is a simplified flow chart showing the production of road tars from bituminous coal.

12. Asphalt Cement

a. The consistency of asphalt cement varies in relation to the amount of volatile substances in the residue. The hardness may be determined by the penetration test. This test measures the distance in units of $\frac{1}{100}$ centimeter that a standard blunt needle of a penetrometer under a force of 100 grams will penetrate a sample of asphalt cement at room temperature of 77° F. (25° C.) in a period of 5 seconds. (See TM 5–530 for test method.) On the basis of relative consistency, nine paving grades of asphalt cement have been established. Each grade is designated by a penetration grade and AP number. (AP means asphalt petroleum, indicating that the asphalt is manufactured from petroleum.)

b. The penetration grades are divided into three groups to indicate hard, medium, and soft asphalt

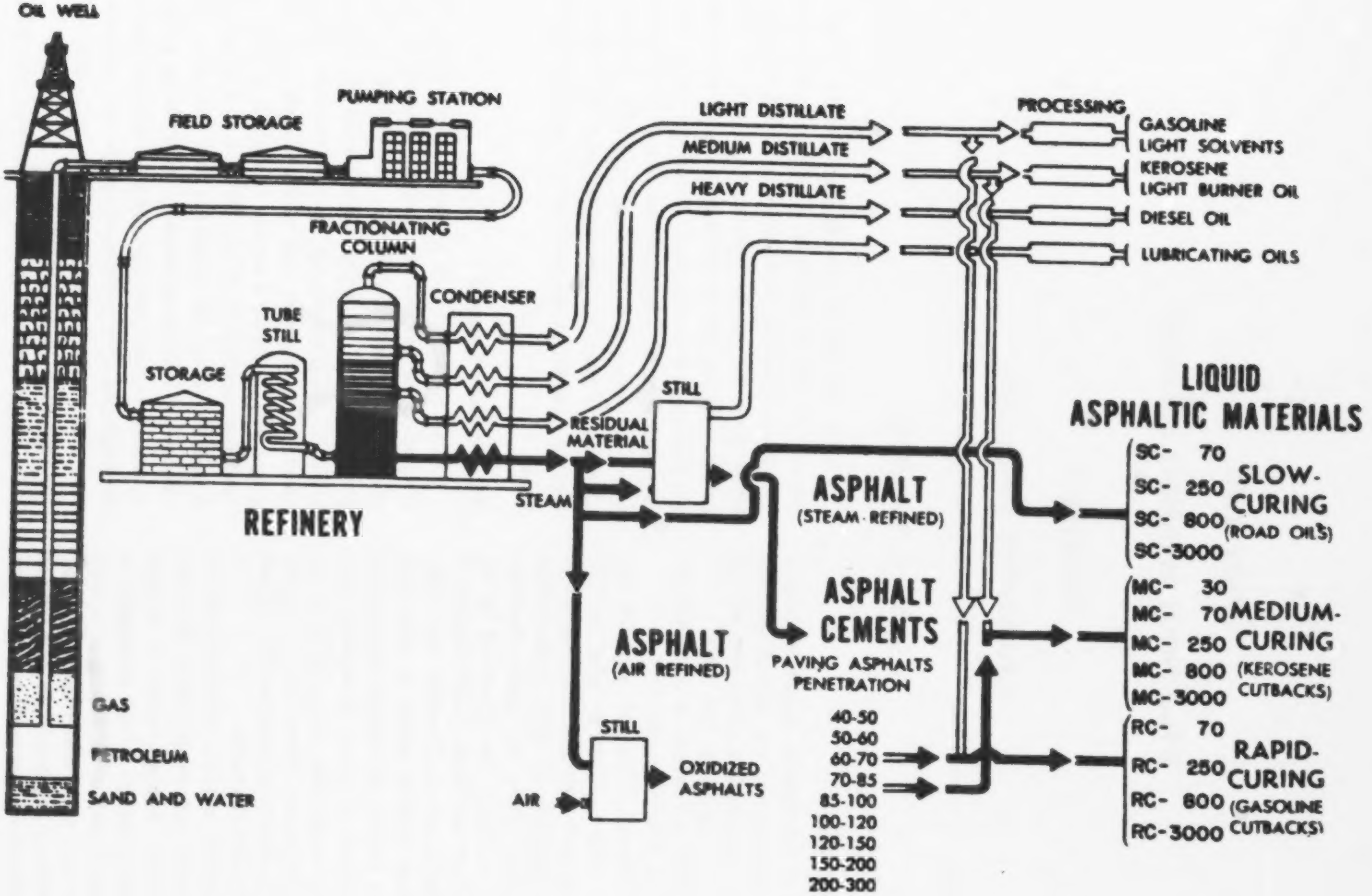

OIL WELL
GAS
PETROLEUM
SAND AND WATER
FIELD STORAGE
PUMPING STATION
FRACTIONATING COLUMN
CONDENSER
TUBE STILL
STORAGE
REFINERY
RESIDUAL MATERIAL
STEAM
STILL
LIGHT DISTILLATE
MEDIUM DISTILLATE
HEAVY DISTILLATE
PROCESSING
GASOLINE
LIGHT SOLVENTS
KEROSENE
LIGHT BURNER OIL
DIESEL OIL
LUBRICATING OILS
ASPHALT
(STEAM-REFINED)
ASPHALT CEMENTS
PAVING ASPHALTS
PENETRATION
40-50
50-60
60-70
70-85
85-100
100-120
120-150
150-200
200-300
ASPHALT
(AIR REFINED)
STILL
AIR
OXIDIZED ASPHALTS
LIQUID ASPHALTIC MATERIALS
SC- 70
SC- 250
SC- 800
SC-3000
SLOW-CURING
(ROAD OILS)
MC- 30
MC- 70
MC- 250
MC- 800
MC-3000
MEDIUM-CURING
(KEROSENE CUTBACKS)
RC- 70
RC- 250
RC- 800
RC-3000
RAPID-CURING
(GASOLINE CUTBACKS)

Figure 2. Simplified flow chart showing recovery of petroleum asphaltic materials.

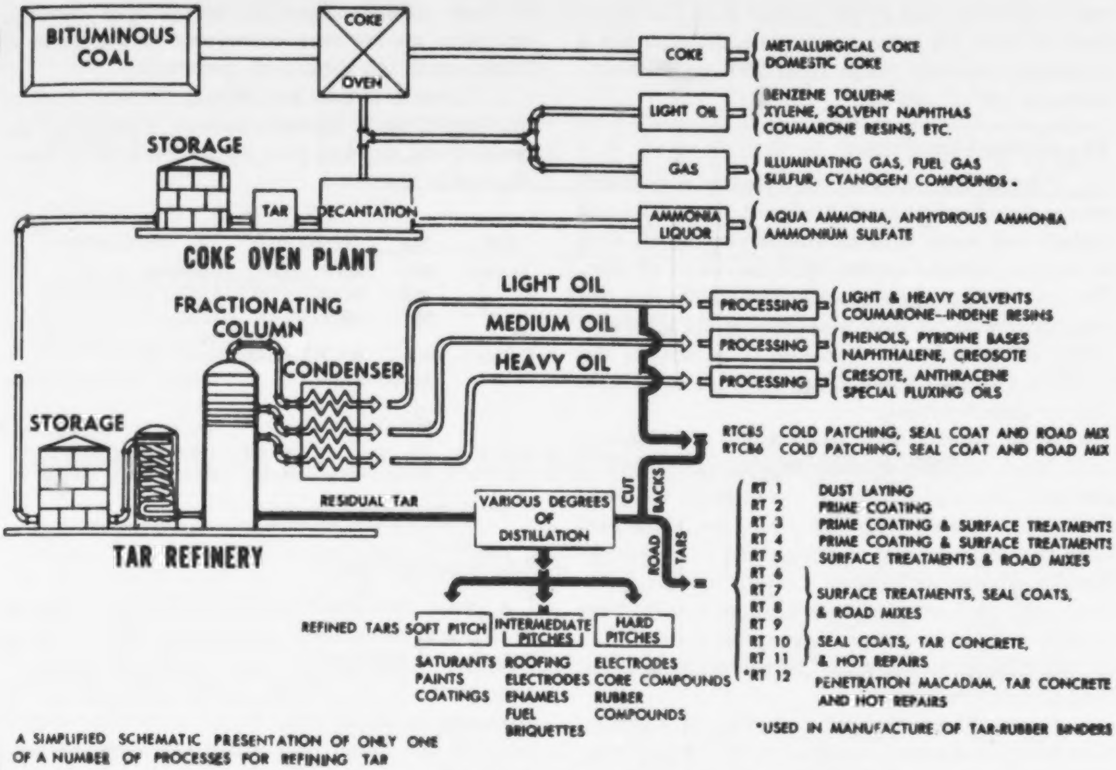

BITUMINOUS COAL
COKE
OVEN
COKE
METALLURGICAL COKE
DOMESTIC COKE
LIGHT OIL
BENZENE TOLUENE
XYLENE, SOLVENT NAPHTHAS
COUMARONE RESINS, ETC.
STORAGE
GAS
ILLUMINATING GAS, FUEL GAS
SULFUR, CYANOGEN COMPOUNDS.
TAR
DECANTATION
AMMONIA LIQUOR
AQUA AMMONIA, ANHYDROUS AMMONIA
AMMONIUM SULFATE
COKE OVEN PLANT
LIGHT OIL
FRACTIONATING COLUMN
MEDIUM OIL
PROCESSING
LIGHT & HEAVY SOLVENTS
COUMARONE—INDENE RESINS
CONDENSER
HEAVY OIL
PROCESSING
PHENOLS, PYRIDINE BASES
NAPHTHALENE, CREOSOTE
PROCESSING
CRESOTE, ANTHRACENE
SPECIAL FLUXING OILS
STORAGE
RTCB5 COLD PATCHING, SEAL COAT AND ROAD MIX
RTCB6 COLD PATCHING, SEAL COAT AND ROAD MIX
CUT BACKS
RESIDUAL TAR
VARIOUS DEGREES OF DISTILLATION
ROAD TARS
TAR REFINERY
RT 1 DUST LAYING
RT 2 PRIME COATING
RT 3 PRIME COATING & SURFACE TREATMENTS
RT 4 PRIME COATING & SURFACE TREATMENTS
RT 5 SURFACE TREATMENTS & ROAD MIXES
RT 6
RT 7
RT 8 SURFACE TREATMENTS, SEAL COATS, & ROAD MIXES
RT 9
RT 10
RT 11 SEAL COATS, TAR CONCRETE, & HOT REPAIRS
*RT 12 PENETRATION MACADAM, TAR CONCRETE AND HOT REPAIRS
REFINED TARS
SOFT PITCH
INTERMEDIATE PITCHES
HARD PITCHES
SATURANTS
PAINTS
COATINGS
ROOFING
ELECTRODES
ENAMELS
FUEL
BRIQUETTES
ELECTRODES
CORE COMPOUNDS
RUBBER COMPOUNDS
*USED IN MANUFACTURE OF TAR-RUBBER BINDERS
A SIMPLIFIED SCHEMATIC PRESENTATION OF ONLY ONE OF A NUMBER OF PROCESSES FOR REFINING TAR

Figure 3. Simplified flow chart showing production of road tars from bituminous coal.

cements. The nine penetration grades, AP number, and relative consistency, or hardness, are as follows:

Penetration grade	AP No.	Relative consistency
40–50	7	Hard
*50–60	6	
60–70	5	
*70–85	4	
85–100	3	Medium
*100–120	2	
120–150	1	
*150–200	0	Soft
200–300	00	

* These penetration grades are no longer readily available. They are included in this manual to facilitate field identification if they should be encountered in the field.

13. Asphalt Cutbacks

a. Composition. Asphalt cutback is produced during the refining process or from asphalt cement heated and cut back with volatile petroleum distillate known as cutterstock. In contrast to asphalt cement, asphalt cutbacks have the advantage of being workable at lower temperatures. Cutterstocks used are naphtha, gasoline, kerosene, jet fuels, diesel oil, or fuel oil.

b. Types. Three types of asphalt cutback have been developed, based on the rate of curing. Asphalt cement containing a highly volatile cutterstock that evaporates rapidly, such as naphtha or gasoline, is a rapid-curing (RC) cutback. Medium-curing (MC) cutbacks contain a less volatile substance, such as kerosene or jet fuels. Slow-curing (SC) cutbacks contain diesel oil or fuel oil. Steps in the process of refining liquid asphaltic materials are shown in figure 2.

c. Grades. The viscosity (resistance to flow) of asphalt cutback varies in accordance with the amount of cutterstock added and the type of asphalt cement used. As the amount of cutterstock is increased, the viscosity decreases. Each of the three types of asphalt cutback (SC, MC, and RC) is produced in four standard grades of kinematic viscosity, 70, 250, 800, and 3000 centistokes. An additional grade, MC–30, is also produced for prime coats. The numerical grades are the lower kinematic viscosity limit at 140° F. (60° C.). The upper limit is twice the lower limit; thus, RC–250 has a kinematic viscosity range from 250 to 500 centistokes at 140° F. (60° C.).

14. Asphalt Emulsions

a. Composition. Asphalt emulsion is a nonflammable liquid substance, produced by combining asphalt and water with an emulsifying agent, such as soap or certain special colloidal clays or dust. The emulsifying agent promotes emulsification and controls certain physical properties of the emulsion. When the emulsion is deposited on a surface, the water and asphalt break (separate), leaving a thin film of asphalt cement.

b. Basic Kinds. Two basic kinds of emulsions have been established according to their electric charge. The use of anionic (negatively charged) emulsions has been somewhat restricted in the past since this type did not easily adhere to negatively charged siliceous aggregates. Certain cationic (positively charged) emulsions will improve adherence to these negatively charged aggregates. In addition, cationic emulsions will coat damp aggregates better than anionic emulsions.

c. Types. Three types of each kind of emulsion have been established according to the setting rate; that is, the rate of separation or breaking of the asphalt from the water. This rate, in general, depends upon the amount and kind of emulsifying agents used. The three basic types of emulsions are rapid setting (RS), medium setting (MS), and slow setting (SS).

d. Advantages and Disadvantages. Besides being nonflammable and liquid at ordinary temperatures, emulsions also have another advantage over asphalt cutbacks. They can be used with damper aggregate than can cutbacks. The use of water in an emulsion is also a disadvantage in freezing weather since it will freeze and break the emulsion. Also, emulsions are difficult to store or stockpile as they tend to break while still in the unopened drums. Because of these disadvantages in storage and freezing, emulsions are not used extensively by the Corps of Engineers in the theater of operations.

e. Viscosity Grades and Mixing Groups. Each of the three types of asphalt emulsion is graded on the basis of viscosity and grouped according to its usage as given below.

Kind	*Type*	*Viscosity Grade*	*Mixing Ability*
Anionic	RS	RS-1, RS-2	Spraying
	MS	MS-2	Mixing and spraying
	SS	SS-1, SS-1h	Mixing and spraying
Cationic	RS-C	RS-2C, RS-3C	Spraying
	MS-C	SM-C	Mixing (sand) and spraying
	MS-C	CM-C	Mixing (coarse agg.) and spraying
	SS-C	SS-C, SS-Ch	Mixing and spraying

Note. C denotes cationic emulsion.
h denotes a lower penetration grade of asphalt cement.

15. Paving Tars

a. Road Tar. Road tars (RT) are manufactured in 12 grades of viscosity, or hardness (RT–1 through RT–12). At a temperature of 77° F., grades 1 through 7 are liquid and grades 8 through 12 are semisolid to solid. The liquid road tars contain more of the liquid coal distillates than the solid grades.

b. Road Tar Cutbacks. Road tars are cut back with a coal tar distillate to form road tar cutbacks (RTCB), which are manufactured only in viscosity grades 5 and 6. Highly volatile coal distillate, such as benzene or a solution of naphthalene in bensol, is used to cut back the heavier grades of road tar to produce these two grades of road tar cutbacks. Like asphalt cutbacks, road tar cutbacks cure rapidly.

c. Viscosity Comparison. The viscosity grades of road tars and road tar cutbacks are comparable to the viscosity grades of asphalt cutbacks and asphalt cement as shown in figure 4. See TM 5–530 for further discussion.

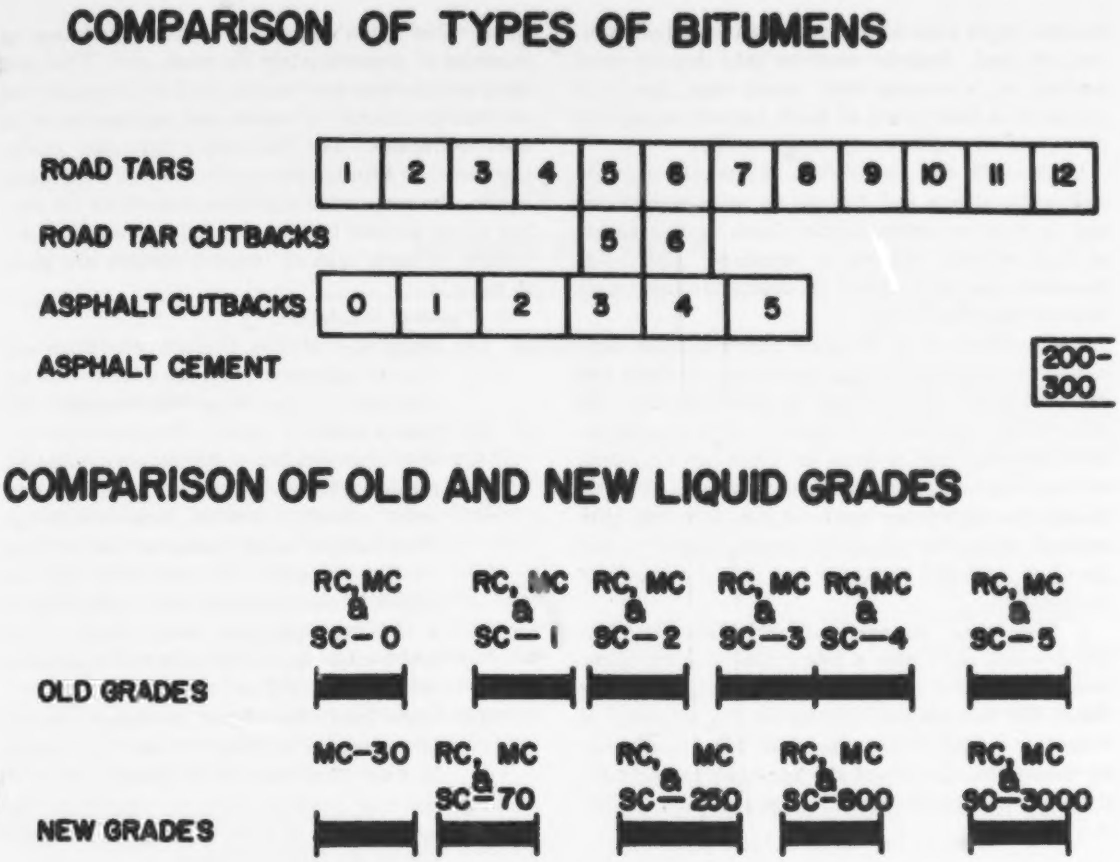

COMPARISON OF TYPES OF BITUMENS
ROAD TARS
1 2 3 4 5 6 7 8 9 10 11 12
ROAD TAR CUTBACKS
5 6
ASPHALT CUTBACKS
0 1 2 3 4 5
ASPHALT CEMENT
200-300
COMPARISON OF OLD AND NEW LIQUID GRADES
RC, MC & SC-0
RC, MC & SC-1
RC, MC & SC-2
RC, MC & SC-3
RC, MC & SC-4
RC, MC & SC-5
OLD GRADES
MC-30
RC, MC & SC-70
RC, MC & SC-250
RC, MC & SC-800
RC, MC & SC-3000
NEW GRADES

Figure 4. Viscosity comparisons of bitumens.

Section II. AGGREGATE

16. Function

Aggregate is combined with a bitumen to form a bituminous wearing surface. It transmits the load from the surface to the base course, takes the abrasive wear of the traffic, and provides a nonskid surface. Aggregate consists of crushed stone, gravel sand, slag, coral, or other similar material and mineral filler.

17. Types of Aggregates

For bituminous construction, aggregates are classified according to particle size. The maximum size of the aggregate varies with construction requirements. Particle size is determined by sorting the materials on standard sieves. (See TM 5-530 for sieve analysis.) The three types of aggregate established on the basis of particle size are discussed below.

a. Coarse Aggregate. Coarse aggregate, usually consisting of pieces of crushed rock, broken gravel, slag, or other mineral material, is retained on a No. 8 standard sieve.

b. Fine Aggregate. Fine aggregate consists of particles of fine sand or small pieces of crushed rock that are small enough to pass through a No. 8 sieve, but are retained on the No. 200 sieve.

c. Mineral Filler. Mineral filler consists of inert nonplastic particles small enough to pass through the No. 200 sieve. Rock dust, hydrated lime, inert fine soil, and portland cement may be used as mineral filler. Most clays are too plastic for this purpose.

18. Characteristics

a. Size and Shape. The interlocking action of the aggregate in a bituminous surface is more pronounced when angular shaped, rough-textured particles are used. Angular particles may require more asphalt for a coating than round ones, but it is desirable to incorporate as much asphalt as possible for durability without impairing stability.

b. Strength and Durability. Aggregate must be sufficiently strong and durable to resist weathering and to hold up under applied loads over a period of time without cracking or breaking. TM 5-530 discusses the tests used to determine aggregate strength and durability.

c. Cleanliness and Moisture Content. The individual particles of the aggregate must be clean and dry to permit the bitumen to penetrate into the pores to hold the particles together. If the aggregate is coated with clay or dust, or if the pores are wet, the bitumen will not penetrate or adhere. For hot mixes, the aggregates must be hot and dry. For cutback mixes, the moisture content should be less than 2 percent and generally less than 5 percent for an emulsion.

d. Wetability. An aggregate which may be clean and dry and not retain a bituminous coating in the presence of water is hydrophilic. Aggregates which retain the bituminous coating in the presence of water are hydrophobic. Standard laboratory tests for the specific gravity of the aggregate, absorption, stripping, and percentage of moisture are described in TM 5-530.

19. Gradation

a. Blending. The three types of aggregates discussed in paragraph 17 may be blended in different proportions to produce various aggregate gradations. Gradation of the particles largely determines the mechanical stability of the bituminous mix. Some types of bituminous wearing surfaces require an aggregate gradation with a wide range of particle sizes; other types require a uniform gradation of particles of approximately the same size. Trial and error calculations are usually used to determine the percentage (blend) of stockpiled aggregates to be used in the mix. The four major aggregate gradations used in bituminous construction are discussed below. Recommended aggregate gradations for paving mixes, surface treatments, and penetration macadams for each type of wearing surface are given in table II.

b. Types of Gradation.

(1) *Uniform gradation.* Uniform gradation consists of aggregate particles that are all approximately the same size, usually less than 1 inch.

(2) *Macadam gradation.* Macadam-graded aggregate consists of uniformly graded particles, usually 1 inch or larger. Although there may be some variation, the particles are approximately the same size. For example, a macadam gradation designated as a 1½-inch aggregate may include 1-inch and 2-inch pieces, but most of the particles will be about 1½ inches.

(3) *Open gradation.* Open gradation consists of aggregate ranging in size from coarse to fine. Open spaces, or voids, remain in the mix because there is insufficient fine aggregate or mineral filler to fill the voids left by the larger particles.

(4) *Dense gradation.* Dense-graded aggregate blends are a well-graded mix of course aggregate, fine aggregate, and mineral filler. In contrast to the open gradation, dense-graded aggregate has only a few voids because the fine particles and the mineral filler fill up the voids around the coarse aggregate.

CHAPTER 4

BITUMINOUS DESIGN

Section I. BITUMEN SELECTION

20. Introduction

Bituminous mix design consists of selecting the bitumen and aggregate gradation, blending aggregates to conform to the selected gradation, determining the optimum between content, and calculating the job mix formula. Once the percentages of materials are determined, the total quantity of materials to be used on the project must be calculated. The design of a typical high-type mix will be discussed in detail in this chapter. Lower type mixes are designed by the same method, although many steps are often omitted because the allowable variations in these mixes are great enough that accurate constituent determination is not necessary.

21. Bitumen Selection Criteria

The selection of a particular bituminous material depends on the type of pavement, temperature extremes, rainfall, type and volume of traffic, and type and availability of equipment. In general, hard penetration grades of asphalt cement are used in warm climates and softer penetration grades in colder climates. Heavier grades of asphalt cutbacks and tars are usually used in warm regions, the lighter grades in cool regions. Asphalt cements are generally more suitable for high traffic volumes than cutbacks. Asphalts and tars will not necessarily bond to each other; thus, bonding also becomes a consideration in bitumen selection. Table I is a guide for the selection of bitumens. Temperature extremes may dictate the use of a different grade of bitumen than that recommended in the table.

Table I. Recommended Use of Bitumens for Bituminous Road Construction (Average Fair-Weather Construction)[1]

Purpose or use	Grade or Designation					
	CB—Asphalt Cutback[2]			AC Asphalt cement with a penetration of	AE Anionic and cationic asphalt emulsion	RT-RTCB Road tar and road tar cutback
	RC Rapid curing	MC Medium curing	SC Slow curing			
Dust palliative	----	MC-30, 70, 250	SC-70, 250	----	SS-1, 1h	RT-1
Prime coat:						
Tightly bonded surfaces	----	MC-30	----	----	----	RT-2
Loosely bonded—fine-grained surfaces.	----	MC-70	SC-70	----	----	RT-3
Loosely bonded—Coarse-grained surfaces.	----	MC-250	SC-250	----	----	RT-4
Tack coat	RC-250, 800	MC-250, 800	----	200-300	RS-1, 2	RT-4, 5, 6, 7, 8, 9
Surface treatment and seal coat:						
Coarse sand cover	RC-70, 250	MC-250, 800	----	----	RS-1, 2	
Clean coarse aggregate cover.	RC-250, 800, 3000	MC-800	----	120-150, 200-300	----	RT-6, 7, 8, 9, 10
Graded gravel aggregate cover.	----	MC-250, 800	SC-800	----	----	
Gravel mulch	----	MC-250	SC-250	----	----	

[1] Prevailing temperature during construction also affects selection of bitumen and may be the determining factor rather than size and gradation of aggregate.

[2] CAUTION: Do not overheat aggregate when cutbacks are used to produce hot mixes. Conversion chart between old and new liquid grades in figure 4.

Table 1. Recommended Use of Bitumens for Bituminous Road Construction (Average Fair-Weather Construction)—Continued [1]

Purpose or use	Grade or Designation					
	CB—Asphalt Cutback[2]			AC Asphalt cement with a penetration of	AE Anionic and cationic asphalt emulsion	RT-RTCB Road tar and road tar cutback
	RC Rapid curing	MC Medium curing	SC Slow curing			
Mixed-in-place—Road mix						
Open-graded aggregate:						
Sand	RC-70, 250	MC-800	----	----	----	RT-6
Maximum diameter 1 in., high percentage passing No. 10.	----	MC-800	----	----	MS-2	
Macadam aggregate	RC-250, 800	----	----	85-100	MS-2	RT-7
Dense-graded aggregate:						
High percentage passing No. 200	----	MC-250	SC-250	----	SS-1h	RT-5, 6, 7
Maximum diameter 1 in., medium percentage passing No. 200.	----	MC-250, 800	SC-250, 800	----	SS-1	RT-6, 7, 8, 9
Premix or cold patch:						
Open-graded aggregate	RC-250	MC-800	SC-800	----	MS-2	RT-5, 6, 7, 8, or RTCB-5, 6.
Dense-graded aggregate	----	MC-250	SC-250	----	----	
Cold-laid plant mix:						
Open-graded aggregate:						
Sand	RC-250, 800	----	----	----	MS-2	
Maximum diameter 1 in., high percentage passing No. 10.	RC-800	----	SC-800	----	MS-2	
Macadam aggregate	RC-800, 3000	----	----	----	----	
Dense-graded agagregate:						
High percentage passing No. 200	----	MC-800	SC-800	----	SS-1	RT-5, 6, 7, 8, 9
Maximum diametaer 1 in., medium percentage passing No. 200	----	MC-800	SC-800	----	SS-1	
Aggregate precoating followed with asphalt.	----	MC-30	SC-70	----	----	
Hot-laid plant mix	RC-3000	MC-3000	SC-3000	85-100, 120-150	----	RT-11, 12
Penetration macadam:						
Cold weather	RC-800, 3000	----	SC-3000	120-150	RS-1	RT-10, 11
Hot weataher	----	----	----	85-100	RS-1	RT-12

[1] Prevailing temperature during construction also affects selection of bitumen and may be the determining factor rather than size and gradation of aggregate

[2] CAUTION: Do not overheat aggregate when cutbacks are used to produce hot mixes. Conversion chart between old and new liquid grades in figure 4.

22. Asphalt Cement

Asphalt cement is usually used in hot-mix pavements. It is usually a solid at a temperature of 77° F. To make it fluid enough for mixing with aggregate or for spraying, asphalt cement must be heated to a temperature ranging from 250° F. to 350° F. A disadvantage of asphalt cement is that adequate heating equipment may not always be available. The various penetration grades are suitable for different uses, including plant mixes, penetration macadam, and surface treatent.

23. Asphalt Cutbacks

The different types and grades of asphalt cutbacks may be used with various climatic conditions for different types of pavement. The cutterstock evaporates, leaving asphalt cement as the active bonding and waterproofing agent. Prevailing atmospheric temperature during construction is a factor that must be considered in selecting the grade of asphalt cutback. Lighter grades are usually used in cool weather. If the preferred grade of a given type of asphalt cutback is not available, a comparable grade of another type may be substituted. For example, RC–70 may be used instead of MC–70, or RC–3000 instead of MC–3000, without seriously affecting the finished structure. Light grades of asphalt cutback may be produced in the field by adding solvents to asphalt cements or to the heavier grades of asphalt cutback. Field manufacture of asphalt cutback is discussed in chapter 7.

24. Asphalt Emulsions

The mixing grades of asphalt emulsions can be mixed with damp aggregate with little or no heating. Recommended usage is dependent on the setting rate and mixing ability. Emulsions are used for surface treatment, for road and plant mixes, and for crack and joint filling.

25. Paving Tars

Since tars will not dissolve in petroleum distillates, they can be used in areas where asphalt would be unsuitable, such as refueling aprons at airfields where petroleum distillates are likely to be spilled. Because tars have greater penetrating qualities than asphalts, they are preferable when penetration is critical. Hot tar mixes are used for plant mixes, surface treatments, penetration macadams, crack fillers, and similar uses. Road tar cutbacks are used for patching mixes, surface treatments, and road mixes. Open flame must not be used near storage, tanks, and drums as road tar cutbacks are highly flammable. Tars are more susceptible to temperature changes than asphalts. They become soft at high temperatures, and brittle at low temperatures.

Section II. AGGREGATE GRADATION SELECTION

26. Preliminary Investigations

Before any specific aggregates can be definitely included in a mix design, preliminary investigations of these aggregates must be made. Then physical properties must conform to those set forth in paragraph 18. A complete analysis, as described in TM 5–530, must be made and the available quantities determined.

27. Gradation Selection Criteria

Once the quality and availability of aggregate are determined, the criteria given in table II is used to select the gradation specification.

a. Use of Mix. Surface course, binder course, road mix, etc.

b. Type of Binder. Asphalt cement or tar.

c. Tire. Pressure. 100 psi or under—low pressure tires; over 100 psi—high pressure tires.

d. Maximum Aggregate Size.

(1) Maximum size of available aggregate.

(2) Maximum size of surface course aggregate mechanically spread—one-half the surface course thickness. Maximum size of all binder courses and hand spread surface course—two-thirds course thickness.

(3) The maximum size (100 percent passing the designated size) shall be the minimum of the two choices above.

Table II. Gradation Specification Limits for Bituminous Construction

Sieve designation (square openings)	Percentage passing by weight																	
	Maximum particle size in inches																	
	2 in.			1½ in.			1 in.			¾ in.			½ in.			⅜ in.		
	PAVEMENTS—PLANT MIXES																	
	Asphalt mixture—surface course—low pressure tires (100 psi and under)																	
				Gradation 1			Gradation 2			Gradation 3			Gradation 4			Gradation 5		
				A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
1½ in.				100	100	100	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1 in.				79–95	83–96	86–98	100	100	100	-----	-----	-----	-----	-----	-----	-----	-----	-----
¾ in.				70–84	74–86	78–90	80–95	84–96	90–98	100	100	100	-----	-----	-----	-----	-----	-----
½ in.				61–75	66–79	71–84	68–86	74–89	79–93	80–95	84–96	87–98	100	100	100	-----	-----	-----
⅜ in.				54–68	60–72	65–78	60–77	66–82	72–87	72–86	76–88	80–92	79–94	81–95	85–96	100	100	100
No. 4				42–54	48–60	54–66	45–60	52–68	60–75	55–70	61–74	67–80	59–73	64–80	72–85	75–95	78–95	80–95
No. 8				33–45	39–51	45–57	34–49	41–57	49–64	43–57	49–62	56–68	46–60	53–67	60–73	60–79	63–83	66–86
No. 16				26–37	31–42	37–48	26–40	33–47	40–54	34–46	39–51	46–57	36–49	42–54	48–60	46–65	49–68	52–72
No. 30				19–29	23–33	29–38	19–30	25–37	30–43	26–36	30–40	36–46	28–38	32–42	37–48	33–51	36–54	38–58
No. 50				14–22	17–25	21–29	14–23	18–28	21–32	18–27	21–30	26–34	19–28	22–30	26–35	21–37	24–40	26–43
No. 100				8–14	10–16	13–19	8–16	11–18	13–21	10–17	13–20	16–22	11–18	13–20	16–22	12–24	14–26	16–28
No. 200				3–6	3.5–6.5	4–7	3–7	3.5–7.6	4–8	3–7	3.5–7.5	4–8	4–8	4–8	4–8	5–9	6–10	7–11
	Asphalt mixture—surface course—high pressure tires (over 100 psi)—(optional for low pressure tires)																	
							Gradation 6			Gradation 7								
							A	B	C	A	B	C						
1 in.							100	-----	-----	-----	-----	-----						
¾ in.							86–97	-----	-----	100	-----	-----						
½ in.							76–90	-----	-----	82–96	-----	-----						
⅜ in.							69–83	-----	-----	79–90	-----	-----						
No. 4							55–70	-----	-----	60–73	-----	-----						
No. 8							45–59	-----	-----	46–60	-----	-----						
No. 16							35–48	-----	-----	34–48	-----	-----						
No. 30							26–38	-----	-----	24–38	-----	-----						
No. 50							17–29	-----	-----	15–28	-----	-----						
No. 100							10–20	-----	-----	8–17	-----	-----						
No. 200[1]							3–6	-----	-----	3–6	-----	-----						

Asphalt mixture—binder course—high and low pressure tires

	Gradation 8			Gradation 9			Gradation 10			Gradation 11			Gradation 12		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
2 in.	100	100	100	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
1½ in.	79–95	81–95	82–96	100	100	100	-----	-----	-----	-----	-----	-----	-----	-----	-----
1 in.	68–84	70–86	71–88	73–95	75–95	79–95	100	100	100	-----	-----	-----	-----	-----	-----
¾ in.	60–75	62–78	64–79	64–83	67–85	70–87	72–95	75–95	81–96	100	100	100	-----	-----	-----
½ in.	52–67	54–69	56–72	55–73	59–77	62–80	61–82	65–85	69–89	70–95	74–95	77–95	100	100	100
⅜ in.	46–60	48–63	50–66	48–65	52–69	55–73	53–72	58–76	62–81	60–80	64–84	68–88	71–95	75–95	78–95
No. 4	32–47	34–49	37–52	35–51	39–55	42–58	38–54	43–59	48–66	42–60	47–65	52–70	50–71	54–75	59–80
No. 8	22–37	24–39	27–42	26–40	29–45	33–49	28–43	32–47	37–53	30–49	36–54	29–57	36–56	40–60	45–66
No. 16	17–30	18–31	20–34	19–32	22–36	25–39	20–34	24–38	28–43	23–39	27–43	29–46	26–44	29–48	34–52
No. 30	12–23	14–24	15–26	14–25	16–27	18–30	15–27	17–29	20–33	17–30	19–33	22–36	19–34	22–37	25–40
No. 50	8–18	9–18	10–19	10–18	11–20	12–21	10–20	11–22	14–24	12–23	13–24	15–26	13–25	15–27	17–29
No. 100	5–12	5–12	6–14	5–12	6–13	7–14	7–14	7–15	8–16	7–16	8–17	9–18	9–18	10–19	11–19
No. 200[1]	3–7	3–7	3–7	3–7	3–7	3–7	3–7	3–7	3–7	3–7	3–7	3–7	4–9	4–9	4–9

Tar mixture—surface course—low pressure tires (100 psi and under)

							Gradation 13			Gradation 14			Gradation 15		
							A	B	C	A	B	C	A	B	C
1 in.							100	100	100	-----	-----	-----	-----	-----	-----
¾ in.							78–95	80–95	84–96	100	100	100	-----	-----	-----
½ in.							68–85	71–88	75–90	76–95	80–95	85–96	100	100	100
⅜ in.							57–75	62–82	66–85	67–85	73–89	79–93	75–95	80–95	86–96
No. 4							40–58	47–65	52–70	50–66	58–73	65–80	55–70	63–80	70–84
No. 8							28–46	35–51	40–58	38–53	43–58	53–68	38–54	48–64	54–69
No. 16							20–35	26–40	30–47	28–41	32–46	41–55	27–41	36–49	41–55
No. 30							13–25	18–30	22–36	19–30	23–36	29–42	18–29	24–36	28–42
No. 50							8–17	12–21	15–26	12–21	15–25	18–29	10–20	15–25	18–29
No. 100							4–12	7–14	9–18	6–14	9–16	11–18	6–13	9–17	11–19
No. 200[1]							2–8	4–10	4–10	4–10	4–10	6–10	4–10	4–10	6–10

Table II. Gradation Specification Limits for Bituminous Construction—Continued

Sieve designation (square openings)	Percentage passing by weight																	
	Maximum particle size in inches																	
	2 in.			1½ in.			1 in.			¾ in.			½ in.			⅜ in.		
	Tar mixture—binder course—high and low pressure tires																	
				Gradation 16														
				A	B	C												
1½ in.				100	-----	-----												
1 in.				70–95	-----	-----												
¾ in.				56–84	-----	-----												
½ in.				44–75	-----	-----												
⅜ in.				36–65	-----	-----												
No. 4				20–95	-----	-----												
No. 8				12–33	-----	-----												
No. 16				6–23	-----	-----												
No. 30				2–15	-----	-----												
No. 50				0–8	-----	-----												
No. 100				0–4	-----	-----												
	PAVEMENTS AND SURFACES—ROAD MIXES																	
	Bituminous mixture—surface source																	
							Gradation 17			Gradation 18			Gradation 19					
							A	B	C	A	B	C	A	B	C			
1 in.							100	-----	-----	-----	-----	-----	-----	-----	-----			
¾ in.							85–100	-----	-----	100	-----	-----	-----	-----	-----			
½ in.							72–95	-----	-----	82–100	-----	-----	-----	-----	-----			
⅜ in.							61–90	-----	-----	68–95	-----	-----	100	-----	-----			
No. 4							43–79	-----	-----	48–82	-----	-----	57–88	-----	-----			
No. 8							32–68	-----	-----	35–71	-----	-----	41–76	-----	-----			
No. 16							24–56	-----	-----	26–60	-----	-----	30–64	-----	-----			
No. 30							18–44	-----	-----	20–48	-----	-----	22–52	-----	-----			
No. 50							13–32	-----	-----	14–38	-----	-----	15–40	-----	-----			
No. 100							9–21	-----	-----	10–25	-----	-----	10–26	-----	-----			
No. 200 [1]							5–12	-----	-----	5–12	-----	-----	5–12	-----	-----			

BITUMINOUS SURFACES

	Penetration macadam																	
	Gradation 20[2]						Gradation 21			Gradation 22								
	A	B	C				A	B	C	A	B	C						
2½ in.	100	-----	-----				-----	-----	-----	-----	-----	-----						
2 in.	90–100	-----	-----				-----	-----	-----	-----	-----	-----						
1½ in.	25–70	-----	-----				-----	-----	-----	-----	-----	-----						
1 in.	0–15	-----	-----				100	-----	-----	-----	-----	-----						
¾ in.	0–8	-----	-----				90–100	-----	-----	100	-----	-----						
½ in.	0–5	-----	-----				55–80	-----	-----	90–100	-----	-----						
⅜ in.	-----	-----	-----				20–55	-----	-----	40–75	-----	-----						
No. 4	-----	-----	-----				0–10	-----	-----	5–25	-----	-----						
No. 8	-----	-----	-----				0–5	-----	-----	0–5	-----	-----						

	Surface treatments—single or multiple																	
				Gradation 23			Gradation 24			Gradation 25			Gradation 26[3]			Gradation 27[3]		
				A	B	C	A	B	C	A	B	C	A	B	C	A	B	C[4]
1½ in.				100	-----	-----	-----	-----	-----									
1 in.				90–100	-----	-----	100	100	-----									
¾ in.				40–75	-----	-----	90–100	90–100	-----	100	100							
½ in.				15–35	-----	-----	20–55	45–75	-----	90–100	90–100		100					
⅜ in.				0–15	-----	-----	0–15	20–55	-----	40–70	40–75		85–100			100	100	
No. 4				0–5	-----	-----	0–5	0–10	-----	0–15	5–25		10–30			85–100	95–100	100
No. 8				-----	-----	-----	-----	0–5	-----	0–5	0–5		0–10			10–40	70–92	50–100
No. 16				-----	-----	-----	-----	-----	-----	-----	-----					0–10	45–80	0–5
No. 30				-----	-----	-----	-----	-----	-----	-----	-----						25–55	
No. 50				-----	-----	-----	-----	-----	-----	-----	-----						5–30	
No. 100				-----	-----	-----	-----	-----	-----	-----	-----						0–8	

---

[1] Fraction passing No. 200 sieve shall conform to the following gradation limits:

Grain size (in.)	Percent fines
0.05	70–100
0.02	35–65
0.005	10–22

[2] Maximum particle size is 2½ inches.

[3] Clean sand or sand gravel may be used instead of crushed rock.

[4] Maximum particle size will pass No. 4 sieve.

28. Types of Mix Gradation

Aggregate and mineral filler may be combined to produce a dense-graded or open-graded mix.

a. Dense-Graded Mix. Dense graded infers that there exists a continuous gradation of particle sizes from coarse to very fine. The smaller particles fill the voids between larger particles, thereby increasing the unit weight.

b. Open-Graded Mix. Open graded means that both coarse and fine particles are present in a continuous gradation but which, lacking sufficient fine material has considerable number of voids and, therefore, less density.

c. Advantages and Disadvantages of Gradation Types. Dense-graded aggregate is more impervious to water and provides more protection to base and subgrade than does open-graded material. Dense-graded mixes usually require less maintenance, and the asphalt life of such mixes is prolonged. Dense-graded mixes require more precise determination and control of the bitumen aggregate ratio; because of the increased voids in open-graded aggregate, the percent of bituminous material is sometimes less critical.

d. Gradation Variables. Some low- and intermediate-type mixes have an allowable variation in gradation great enough to allow the use of naturally occurring or man-made aggregate without any special preparation. High-type mixes and some intermediate-types have such small allowable gradation variations that more than one aggregate gradation must be combined in a blend to obtain the desired gradation.

Example: An asphalt finisher is to be used to place a 2-inch asphaltic concrete surface course on an MSR. One-inch maximum size aggregate is available. A limited supply of limestone dust is available for use as a mineral filler. Select an aggregate gradation if the bitumen is asphalt cement.

Solution: Use—surface course (2 inches thick)
Bitumen—asphalt cement
Tire pressure—low (trucks have less than 100 psi tire pressure)
Maximum aggregate size—
Available—1 inch
Method of placement—surface course, machine placed, therefore 2 inches $\times \frac{1}{2} = 1$inch
Therefore the maximum aggregate size is 1 inch. Gradation type open graded to conserve limestone dust
Final selection—*Gradation 2A* from table II.

29. Aggregate Blending

Aggregate blending is the proportioning of several aggregate gradations to obtain one desired aggregate gradation. The usual procedure is to mix three or four aggregates from various sources. The results of gradation tests on each source are recorded on DD Form 1207 (Grain Size Distribution Graph—Aggregate Grading Chart) (fig. 5) or are presented in tabular form. DD Form 1217 (Bituminous Mix Design—Aggregate Blending) is used as a worksheet in calculating the aggregate blend. Although there are several methods of determining the correct blend, the trial and error method will be used herein as other methods require complicated graphs and formulas. This method is best illustrated by an aggregate blending example. Gradation 2A (as determined in paragraph 28) will be used as the specification limits. The gradations of the stockpile samples are obtained from figure 5.

a. Gradation of Material. The sieve sizes and percents passing are recorded for all four aggregates in the block titled "Gradation of Material" on DD Form 1217 (1, fig. 6). The specified gradation limits are entered across the "Desired" row of the block for reference. All blanks to the left of the 100 percent passing for each aggregate should be filled in as 100 percent passing also. (100 percent passing a given sieve will also be 100 percent passing all larger sieves.) The data is to be recorded in this block as shown in 1, figure 6.

b. Trial Number One. All data discussed in this subparagraph should be entered in the block titled "Combined Gradation for Blend—Trial No. One" on DD Form 1217 2, fig. 6.

(1) Enter the mean of the specified gradation limits in the "Desired" row.

Example: Find the mean of the specified gradation limits for the $\frac{3}{4}$-inch sieve.

Solution: $\frac{1}{2}(80+95)=87.5$ percent

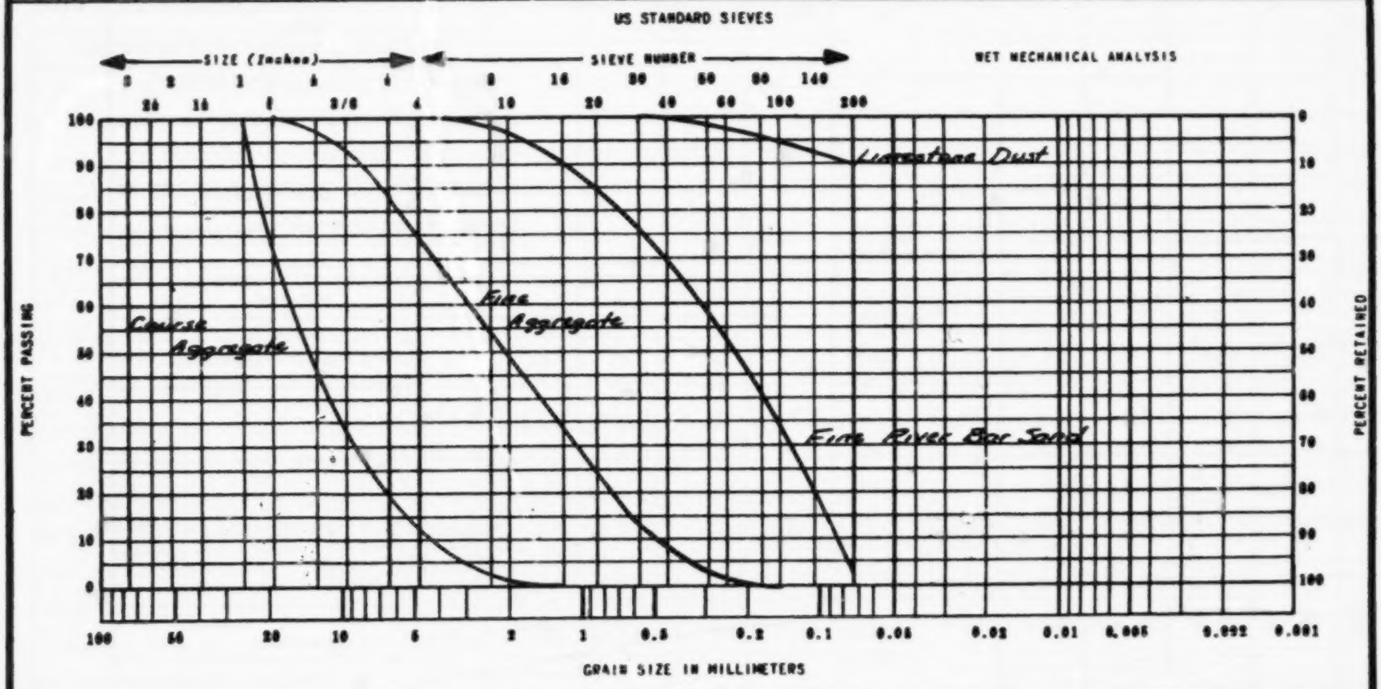
(2) The percent passing for each sieve size and gradation is calculated by using the following formula:

$$\text{percent passing (trial block)} = \frac{\text{percent used (trial block)} \times \text{(gradation of material block)}}{100}$$

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE
30 MAR 65

PROJECT
HIGHWAY #203



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS

TECHNICIAN (Signature)	PLOTTED BY (Signature)	CHECKED BY (Signature)
Sp4 Alexander McMurray	Sp4 Alexander McMurray	Sgt Arthur Price

DD FORM 1 AUG 57 1207

GPO 943037

Figure 6. Aggregate grading chart, DD Form 1207, Gradation of Stockpiled Materials.

1 Gradation of material block

BITUMINOUS MIX DESIGN - AGGREGATE BLENDING

PROJECT Highway #203	JOB No. 47236	DATE 5 Apr 65 AGGREGATE GRADATION NUMBER 2A

GRADATION OF MATERIAL

SIEVE SIZE (To be entered by Technician): →	1"	3/4"	1/2"	3/8"	# 4	# 8	# 16	# 30	# 50	# 100	# 200	
MATERIAL USED	PERCENT PASSING											
Course Aggregate (CA)	100	72	46	33	12	2	0	0	0	0	0	
Fine Aggregate (FA)	100	100	98	94	76	54	33	13	2	0	0	
Fine River Bar Sand (FRBS)	100	100	100	100	100	98	90	76	58	35	3	
Limestone Dust (LSD	100	100	100	100	100	100	100	100	98	95	90	
DESIRED:	100	80-95	68-86	60-77	45-60	34-49	26-40	19-30	14-23	8-16	3-7	

COMBINED GRADATION FOR BLEND - TRIAL NUMBER ____________

SIEVE SIZE (To be entered by Technician): →													
MATERIAL USED	% USED	PERCENT PASSING											
BLEND:													
DESIRED:													

COMBINED GRADATION FOR BLEND - TRIAL NUMBER ____________

SIEVE SIZE (To be entered by Technician): →													
MATERIAL USED	% USED	PERCENT PASSING											
BLEND:													
DESIRED:													

DD FORM 1 DEC 68 1217 PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

2 T ber one

BITUMINOUS MIX DESIGN - AGGREGATE BLENDING		DATE
PROJECT	JOB	AGGREGATE GRADATION NUMBER

GRADATION OF MATERIAL

SIEVE SIZE (To be entered by Technician): →												
MATERIAL USED	PERCENT PASSING											
DESIRED:												

COMBINED GRADATION FOR BLEND - TRIAL NUMBER 1

SIEVE SIZE (To be entered by Technician): →		1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200	
MATERIAL USED	% USED	PERCENT PASSING											
CA	45	45.0	32.4	20.7	14.9	5.4	0.9	0	0	0	0	0	
FA	25	25.0	25.5	24.5	23.5	18.8	13.5	8.3	3.3	0.5	0	0	
FRBS	25	25.0	25.0	25.0	25.0	25.0	24.5	22.5	19.0	14.5	8.8	0.8	
LSD	5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.8	4.5	
BLEND:		100.0	87.9	75.2	68.4	54.2	43.9	35.8	27.3	19.9	13.6	6.3	
DESIRED:		100.0	87.5	77.0	68.5	52.5	41.5	33.0	24.5	18.5	12.0	5.0	

COMBINED GRADATION FOR BLEND - TRIAL NUMBER ________

SIEVE SIZE (To be entered by Technician): →													
MATERIAL USED	% USED	PERCENT PASSING											
BLEND:													
DESIRED:													

DD FORM 1 DEC 68 1217 PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

Figure 6—Continued.

Example: Find the trial percent passing the ¾-inch sieve (coarse aggregate).

Solution: The gradation test shows that 72 percent passed the ⅜-inch sieve at the stockpile.

percent passing (trial block) =

$$\frac{45\times 72}{100} = \text{32.4 percent passing the ⅜-inch sieve}$$

(3) The trial "percent used" values are obtained by estimation. The first estimation should be for the mineral filler "percent used" value. This is done by calculating the percentage necessary to satisfy the No. 200 requirements.

Example: The percent of mineral filler passing the No. 200 sieve is 90.0 at the stockpile. The desired amount passing would be 5 percent with a lower limit of 3 percent.

Solution: An estimation of 4 percent used will be tried: $\frac{4.0\times 90.0}{100}=3.6$ percent. An examination of other gradations contributing to the percent passing shows only 3 percent of the fine river bar sand (FRBS) passing the No. 200 sieve; thus, any normal "percent used" value for the FRBS would affect the percent passing the No. 200 sieve by less than 1. Therefore, 4 percent would be somewhat low and 5 percent should be tried: $\frac{5.0\times 90.0}{100}=4.5$ percent.

(4) The second trial "percent used" is obtained most easily by series of calculations. First, the average of the specified gradation range for the percent passing the *second* largest sieve is calculated (S) This result is centered in the following formula:

$$T=100S\,\frac{100-S}{(100-C)}$$

where: T = The trial percent passing for the coarse aggregate (CA).

S = The mean of the upper and lower limits of the specified gradation range for the percent passing the *second* largest sieve.

C = The percent passing the second largest sieve for the original gradation of coarse aggregate (CA).

Example: From figure 2, 6, gradation range is 80 t 95 and C = 72.

Solution: $S=\frac{1}{2}\,(80+95)=87.5$

$$T=100\times\frac{100-87.5}{100-72}=\frac{100\times 12.5}{28}=44.7 \text{ or 45 percen}$$

(5) The total of the "percent used" colum must always be 100 for all trials. If onl three aggregates are being blended, th intermediate aggregate "percent used" ma be found by subtracting the two "percen used" figures already determined from 100 If more than three gradations are bein blended, the two predetermined "percen used" figures are subtracted from 100 an divided by the number of intermediat gradations. This yields a trial "percen used" for each gradation.

Example: The percent used for the coarse aggregat is 48 and for the fine aggregate is 4 There are two intermediate aggregate (FA and FRBS)

Solution: Intermediate percent used = ½ (100–45– 5) $=\frac{50}{2}=25$ percent. Therefore the firs trial percent used for the intermediat aggregate will be 25 percent.

(6) Each block should be filled in as explaine in (1) above. The columns for each siev are added and compared to the desire gradation range.

c. *Succeeding Trials.* Each succeeding trial shoul be a refinement of the results of the preceding trial Although the results of Trial No. 1 are within th limits of the specified gradation, an effort should b made to obtain a blend as close as possible to th means of the gradation. This allows a slightl greater deviation in the blend; thus, the centra plant will not require adjustment as often. 3, figur 6 is an example of a succeeding trial.

(1) An inspection of the preceding trial i made. Those sieve sizes whose blend i not within the specified gradation rang are noted.

(2) Usually changing the intermediate aggregrates "percent used" will yield result within the specified limits.

(3) The original coarse aggregate and fin aggregate "percent used" figures may re quire changing. There is nothing wron with this as the original figures were guide only.

BITUMINOUS MIX DESIGN - AGGREGATE BLENDING		DATE
PROJECT	JOB	AGGREGATE GRADATION NUMBER

GRADATION OF MATERIAL

SIEVE SIZE (*To be entered by Technician*): →												
MATERIAL USED	PERCENT PASSING											
DESIRED:												

COMBINED GRADATION FOR BLEND - TRIAL NUMBER ____

SIEVE SIZE (*To be entered by Technician*): →													
MATERIAL USED	% USED	PERCENT PASSING											
BLEND:													
DESIRED:													

COMBINED GRADATION FOR BLEND - TRIAL NUMBER 2

SIEVE SIZE (*To be entered by Technician*): →		1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200	
MATERIAL USED	% USED	PERCENT PASSING											
CA	45	45.0	32.9	20.7	14.9	6.4	0.9	0	0	0	0	0	
FA	30	30.0	30.9	29.4	28.2	22.5	16.2	9.9	3.9	0.6	0	0	
FRBS	20	20.0	20.0	20.0	20.0	20.0	19.6	18.0	15.2	11.6	7.0	0.6	
LSD	5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.8	4.5	
BLEND:		100.0	87.4	75.1	68.1	52.9	41.7	32.9	24.1	17.1	11.8	5.1	
DESIRED:		100.0	87.5	77.0	68.5	52.5	41.5	33.0	24.5	18.5	12.0	5.0	

DD FORM 1 DEC 65 **1217** PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

Figure 6—Continued.

Example: In Trial No. 1, the blend values between the No. 4 and No. 200 sieves were high.

Solution: A reduction in the percent passing values is necessary. This is accomplished by reducing the amount of the finer material in the blend. A trial gradation of 45/30/20/5 (CA/FA/FRBS/LSD) is used in an attempt to correct the blend. 3, figure 6 shows Trial Number 2.

d. Final Trials. Once a set of values are obtained that are well within the specified limits, the final trials are made. Inspection of the "percent used" column will show that a relatively large range of values will yield results within the specification limits. The purpose of the final trials is to obtain a blend as close as possible to the mean of the specification limits. The final trials are computed in the same manner as the initial trials except that the "Desired" row should contain the mean value (average of high and low values) of the specifications. Trial No. 2 (3, fig. 6) is close enough to the median; therefore, no further trials are necessary.

e. Reporting. The calculations for the aggregat blending should be checked by an independent part upon completion. Two forms are used to recor this result.

(1) *DD Form 1217.* DD Form 1217 (4 an 5, fig. 6) is used as a reporting form i addition to being a computational form The "Gradation of Material" block is recorded in the same manner as it was i the trial computations. The next block that was used for trial one, should contai the contents of the final trial block copie verbatim.

(2) *DD Form 1207.* DD Form 1207 is use as a graphical record of the aggregat blend. The upper and lower limits of th specified gradation, the mean of the specified gradation, and the calculated fin blend are all plotted on the same grap (the mean is sometimes omitted.) Figur 7 shows the use of DD Form 1207 fo reporting an aggregate blend.

4 Co ed form (front)

BITUMINOUS MIX DESIGN - AGGREGATE BLENDING			DATE 5 Apr —
PROJECT Highway #203		JOB No 47236	AGGREGATE GRADATION NUMBER 2 A

GRADATION OF MATERIAL

SIEVE SIZE (To be entered by Technician): →	1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200	
MATERIAL USED	PERCENT PASSING											
Course Aggregate (CA)	100	72	46	33	12	2	0	0	0	0	0	
Fine Aggregate (FA)	100	100	98	94	75	54	33	13	2	0	0	
Fine River Bar Sand (FRBS)	100	100	100	100	100	98	90	76	58	35	3	
Limestone Dust (LSD)	100	100	100	100	100	100	100	100	98	95	90	
DESIRED:	100	80-95	68-86	60-77	45-60	34-49	26-40	18-30	14-23	8-16	3-7	

COMBINED GRADATION FOR BLEND - TRIAL NUMBER Final

SIEVE SIZE (To be entered by Technician): →		1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200	
MATERIAL USED	% USED	PERCENT PASSING											
CA	45	45.0	32.4	20.7	14.9	5.4	0.9	0	0	0	0	0	
FA	30	30.0	30.0	29.4	28.2	22.5	16.2	9.9	3.9	0.6	0	0	
FRBS	20	20.0	20.0	20.0	20.0	20.0	19.6	18.0	15.2	11.6	7.0	0.6	
LSD	5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.9	4.8	4.5	
BLEND:		100.0	87.4	75.1	68.1	52.9	41.7	32.9	24.1	17.1	11.8	5.1	
DESIRED:		100.0	87.5	77.0	68.5	52.5	41.5	33.0	24.5	18.5	12.0	5.0	

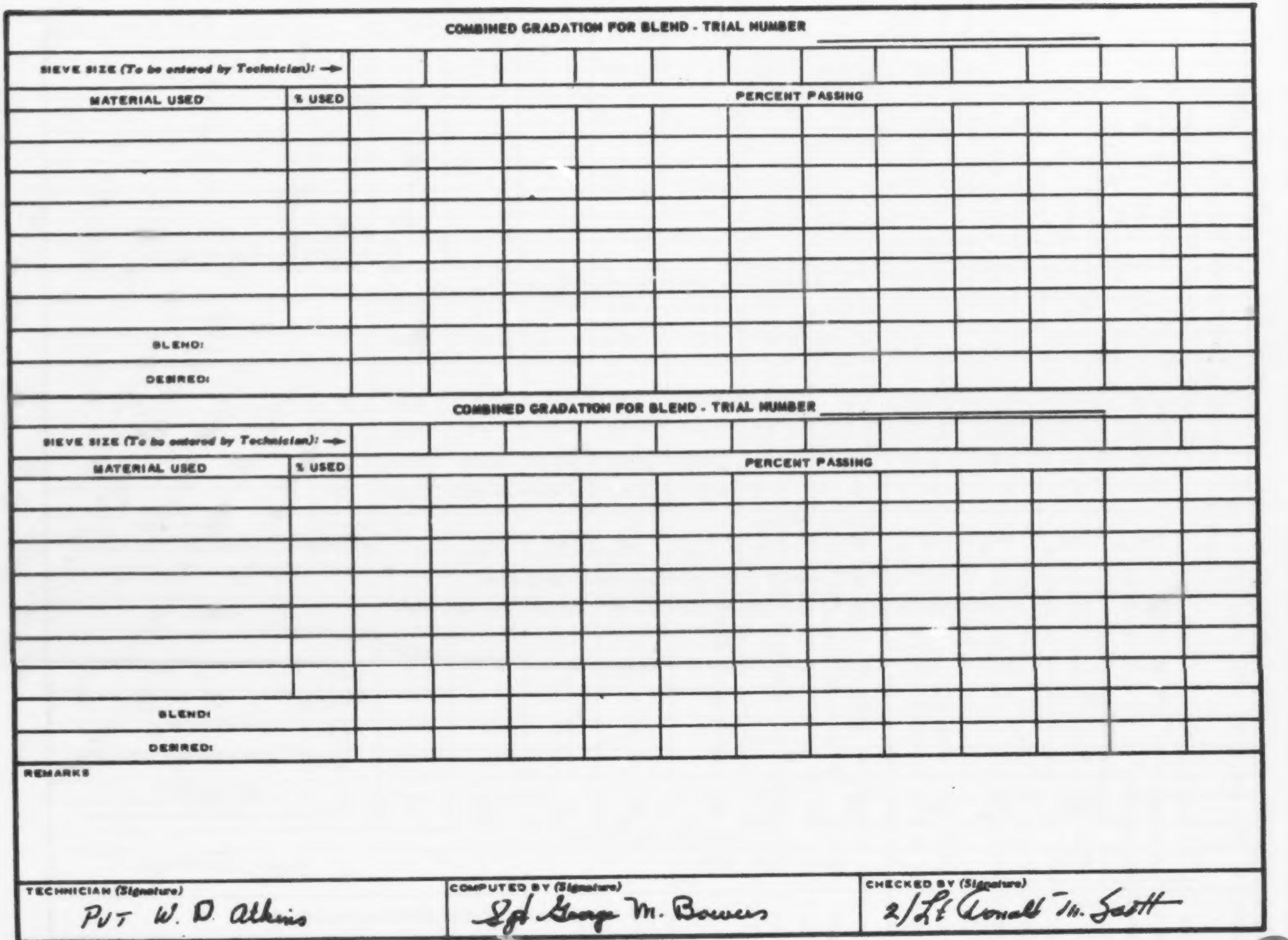
COMBINED GRADATION FOR BLEND - TRIAL NUMBER ______

SIEVE SIZE (To be entered by Technician): →													
MATERIAL USED	% USED	PERCENT PASSING											
BLEND:													
DESIRED:													

DD FORM 1 DEC 66 1217 PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

Figure 6—Continued.

5 Completed form (back)



COMBINED GRADATION FOR BLEND - TRIAL NUMBER													
SIEVE SIZE (*To be entered by Technician*): →													
MATERIAL USED	**% USED**	**PERCENT PASSING**											
BLEND:													
DESIRED:													
COMBINED GRADATION FOR BLEND - TRIAL NUMBER													
SIEVE SIZE (*To be entered by Technician*): →													
MATERIAL USED	**% USED**	**PERCENT PASSING**											
BLEND:													
DESIRED:													

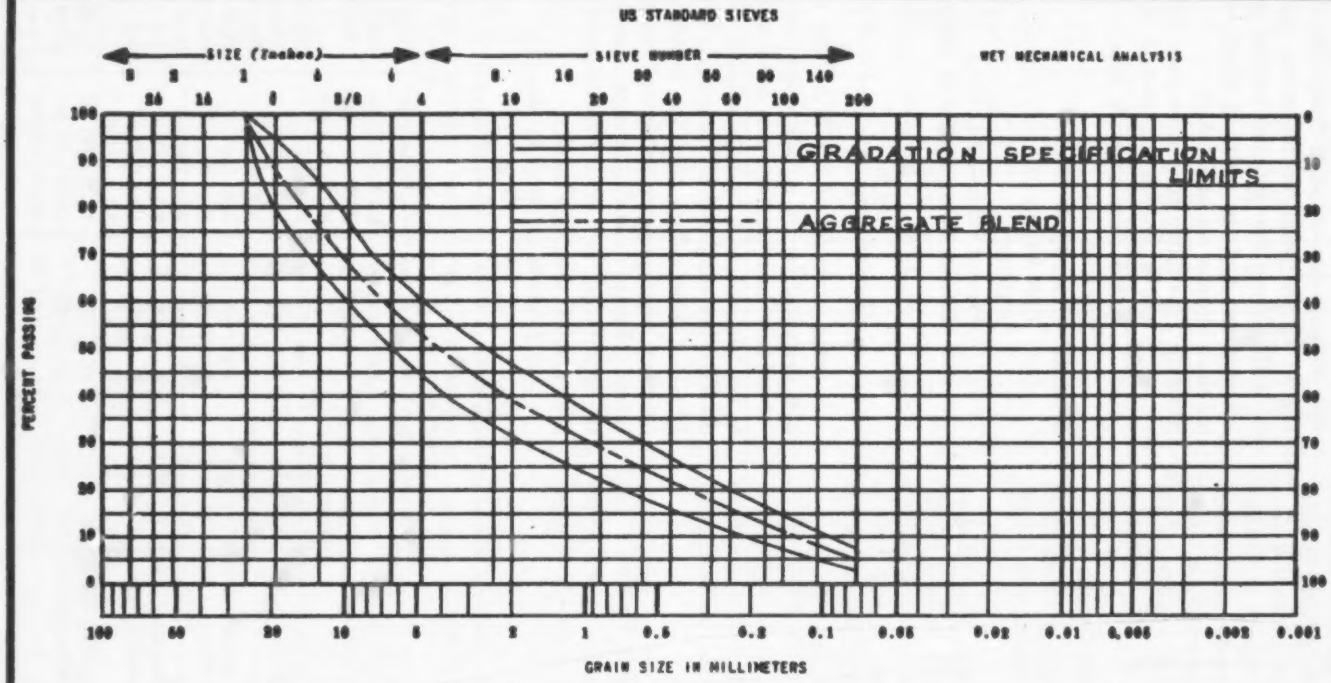
REMARKS

TECHNICIAN (*Signature*) Pvt W. D. Atkins	**COMPUTED BY (*Signature*)** Sgt George M. Bowers	**CHECKED BY (*Signature*)** 2/Lt Donald M. Scott

GRAIN SIZE DISTRIBUTION GRAPH - AGGREGATE GRADING CHART

DATE 30 MAR 65

PROJECT HIGHWAY #203 JOB NO. 47236 SURFACE COURSE



EXCAVATION NUMBER	SAMPLE NUMBER	NATURAL % MOISTURE	w_L	w_P	I_P	CLASSIFICATION	REMARKS

TECHNICIAN (Signature)	PLOTTED BY (Signature)	CHECKED BY (Signature)
Sp/4 Alexander McMurray	Sp/4 Alexander McMurray	Sgt Arthur Price

DD FORM 1 AUG 57 1207

GPO 943937

Figure 7. Grain Size Distribution Graph—Aggregate Grading Chart (DD Form 1207), specification limits for the mix and gradation of the aggregate blend.

Section III. OPTIMUM BITUMEN CONTENT DETERMINATION

30. Marshall Method

The Marshall method must be used to determine the optimum bitumen content of hot-mix pavements where stability and durability are required to withstand the action of high-pressure aircraft tires or heavy road traffic. A modified version of this test is used to determine the optimum bitumen content for cold mixes. A complete treatment of the limitations and testing methods of both versions of the Marshall method is contained in TM 5-530.

31. Reporting of Marshall Test Results

The results of the Marshall test may be sent from the testing laboratory to the unit in one of two ways.

a. Marshall Method Data Sheet. The Marshall Method—Computation of Properties of Asphalt Mixtures (DD Form 1218) (fig. 8) is the laboratory worksheet for the Marshall tests. If this sheet is sent in lieu of the bituminous mix curves, the curves must still be plotted to evaluate the data.

b. Bituminous Mix Curves (DD Form 1219). The bituminous mix curves (fig. 9) are used to present the results of the Marshall test in graphical form. The curves should be smooth without deviations to include extraneous values.

32. Evaluation of Marshall Test Results

Table III is used to evaluate the results of the Marshall test and to obtain an optimum bitumen content.

a. Trial Optimum Bitumen Content. The p cents of bitumen for the unit weight, stabili percent voids—total mix, and percent voids fil with bitumen are obtained from DD Form 1 (fig. 9) for the points on the curves prescribed table III. These four bitumen content percenta are averaged and the result is noted as the t optimum bitumen content (OBC).

Example: The bituminous mix curves shown in ure 9 are for an airfield AC surf course (high-pressure tires). Determ the trial OBC.

Solution: (from fig. 9)

Unit weight ----------------------
Stability --------------------------
Percent voids—total mix-----------
Percent voids filled with bitumen---
Total -----------------------------

$$\text{Average} = \frac{18.7}{4} = 4.7\%\ \text{AC (Trial OB}$$

b. Satisfactoriness of the Mix. The curves next evaluated for the stability, flow, percent vo —total mix, and percent voids filled with bitun at the trial optimum bitumen content. The val obtained are compared to the criteria in table If all of these values meet the criteria, the t optimum bitumen content becomes the (final) timum bitumen content. Should one or more the criteria fail to meet the specifications, the lowing action should be taken:

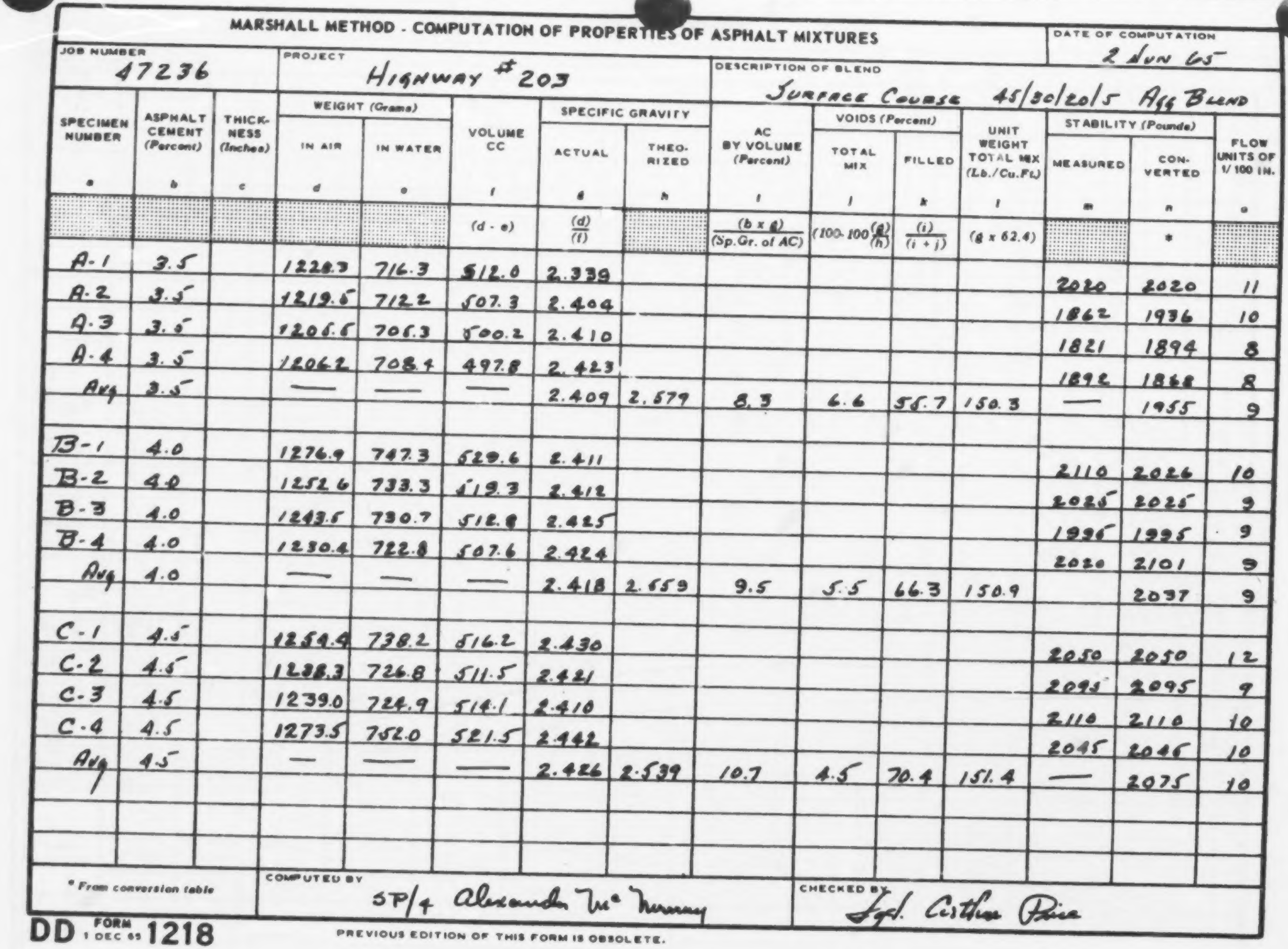
(1) Recheck all computations.

Table III. Criteria for Determination of Optimum Bitumen Content (Marshall Method)

Test property	Type of mix	Point on curve		Criteria	
		For 100 psi tires[1]	For 200 psi tires[1]	For 100 psi tires[1]	For 200 psi tire
Stability	Asphaltic-concrete surface course	Peak of curve	Peak of curve	500 lb or higher	1800 lb or hig
	Asphaltic-concrete binder course	Peak of curve[2]	Peak of curve[2]	500 lb or higher	1800 lb or hig
	Sand asphalt	Peak of curve	-------------	500 lb or higher	------------
Unit weight	Asphaltic-concrete surface course	Peak of curve	Peak of curve	Not used	Not used
	Asphaltic-concrete binder course	Not used	Not used	Not used	Not used
	Sand asphalt	Peak of curve	-------------	Not used	Not used
Flow	Asphaltic-concrete surface course	Not used	Not used	20 or less	16 or less
	Asphaltic-concrete binder course	Not used	Not used	20 or less	16 or less
	Sand asphalt	Not used	Not used	20 or less	16 or less
Percent voids total mix.	Asphaltic-concrete surface course	4 (3)	4 (3)	3-5 (2-4)	3-5 (2-4)
	Asphaltic-concrete binder course	5 (4)	6 (5)	4-6 (3-5)	5-7 (4-6)
	Sand asphalt	6 (5)	-- (-)	5-7 (4-6)	--- (---)
Percent voids filled with bitumen.	Asphaltic-concrete surface course	80 (85)	75 (80)	75-85 (80-90)	70-80 (75-8
	Asphaltic-concrete binder course	70 (75)	60 (65)[2]	65-75 (70-80)	50-70 (55-7
	Sand asphalt	70 (75)	-- (--)	65-75 (70-80)	----- (----

[1] Figures in parentheses are for use with bulk impregnated specific gravity (water absorption by aggregate greater than 2.5 percent).

[2] If the inclusion of asphalt contents of these points in the average causes the voids total mix to fall outside the limits, then the optimum content should be adjusted so that the voids total mix are within the limits.



MARSHALL METHOD - COMPUTATION OF PROPERTIES OF ASPHALT MIXTURES

DATE OF COMPUTATION: 2 Jun 65

JOB NUMBER: 47236

PROJECT: Highway # 203

DESCRIPTION OF BLEND: Surface Course 45/30/20/5 Agg Blend

SPECIMEN NUMBER	ASPHALT CEMENT (Percent)	THICKNESS (Inches)	WEIGHT (Grams)		VOLUME CC	SPECIFIC GRAVITY		AC BY VOLUME (Percent)	VOIDS (Percent)		UNIT WEIGHT TOTAL MIX (Lb./Cu.Ft.)	STABILITY (Pounds)		FLOW UNITS OF 1/100 IN.
			IN AIR	IN WATER		ACTUAL	THEORIZED		TOTAL MIX	FILLED		MEASURED	CONVERTED	
a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
					(d - e)	(d)/(f)		(b x g)/(Sp.Gr. of AC)	(100-100 (g)/(h))	(i)/(i + j)	(g x 62.4)		*	
A-1	3.5		1228.3	716.3	512.0	2.339						2020	2020	11
A-2	3.5		1219.5	712.2	507.3	2.404						1862	1936	10
A-3	3.5		1206.6	706.3	500.2	2.410						1821	1894	8
A-4	3.5		1206.2	708.4	497.8	2.423						1892	1868	8
Avg	3.5		—	—	—	2.409	2.579	8.3	6.6	56.7	150.3	—	1955	9
B-1	4.0		1276.9	747.3	529.6	2.411						2110	2026	10
B-2	4.0		1252.6	733.3	519.3	2.412						2025	2025	9
B-3	4.0		1243.5	730.7	512.8	2.425						1995	1995	9
B-4	4.0		1230.4	722.8	507.6	2.424						2020	2101	9
Avg	4.0		—	—	—	2.418	2.559	9.5	5.5	66.3	150.9		2037	9
C-1	4.5		1254.4	738.2	516.2	2.430						2050	2050	12
C-2	4.5		1238.3	726.8	511.5	2.421						2095	2095	9
C-3	4.5		1239.0	724.9	514.1	2.410						2110	2110	10
C-4	4.5		1273.5	752.0	521.5	2.442						2045	2046	10
Avg	4.5		—	—	—	2.426	2.539	10.7	4.5	70.4	151.4	—	2075	10

* From conversion table

COMPUTED BY: SP/4 Alexander Mc Murray

CHECKED BY: Sgt. Arthur Price

DD FORM 1 DEC 65 1218

PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

Figure 8. Marshall method—computation of properties of asphalt mixtures.

MARSHALL METHOD - COMPUTATION OF PROPERTIES OF ASPHALT MIXTURES

DATE OF COMPUTATION

JOB NUMBER

PROJECT

DESCRIPTION OF BLEND

SPECIMEN NUMBER	ASPHALT CEMENT (Percent)	THICKNESS (Inches)	WEIGHT (Grams)		VOLUME CC	SPECIFIC GRAVITY		AC BY VOLUME (Percent)	VOIDS (Percent)		UNIT WEIGHT TOTAL MIX (Lb./Cu.Ft.)	STABILITY (Pounds)		FLOW UNITS OF 1/100 IN.
			IN AIR	IN WATER		ACTUAL	THEORIZED		TOTAL MIX	FILLED		MEASURED	CONVERTED	
a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
					(d - e)	$\frac{(d)}{(f)}$		$\frac{(b \times g)}{(Sp.Gr. of AC)}$	$(100-100\frac{(g)}{(h)})$	$\frac{(i)}{(i+j)}$	(g x 62.4)		*	
D-1	5.0		1237.9	727.0	510.9	2.423						1875	1875	14
D-2	5.0		1300.0	763.6	536.3	2.424						2130	1981	10
D-3	5.0		1273.6	746.9	526.7	2.418						1900	1824	12
D-4	5.0		1247.9	731.8	516.1	2.418						1855	1855	12
Avg	5.0		—	—	—	2.421	2.519	11.9	3.9	75.3	151.5		1884	12
E-1	5.5		1237.3	724.1	513.2	2.411						1450	1450	12
E-2	5.5		1264.0	740.6	523.4	2.415						1530	1469	14
E-3	6.5		1286.4	752.4	534.0	2.409						1615	1550	13
E-4	5.5		1253.4	733.8	519.7	2.412						1505	1505	16
Avg	5.5		—	—	—	2.412	2.500	13.0	3.6	78.3	150.5		1494	14

* From conversion table

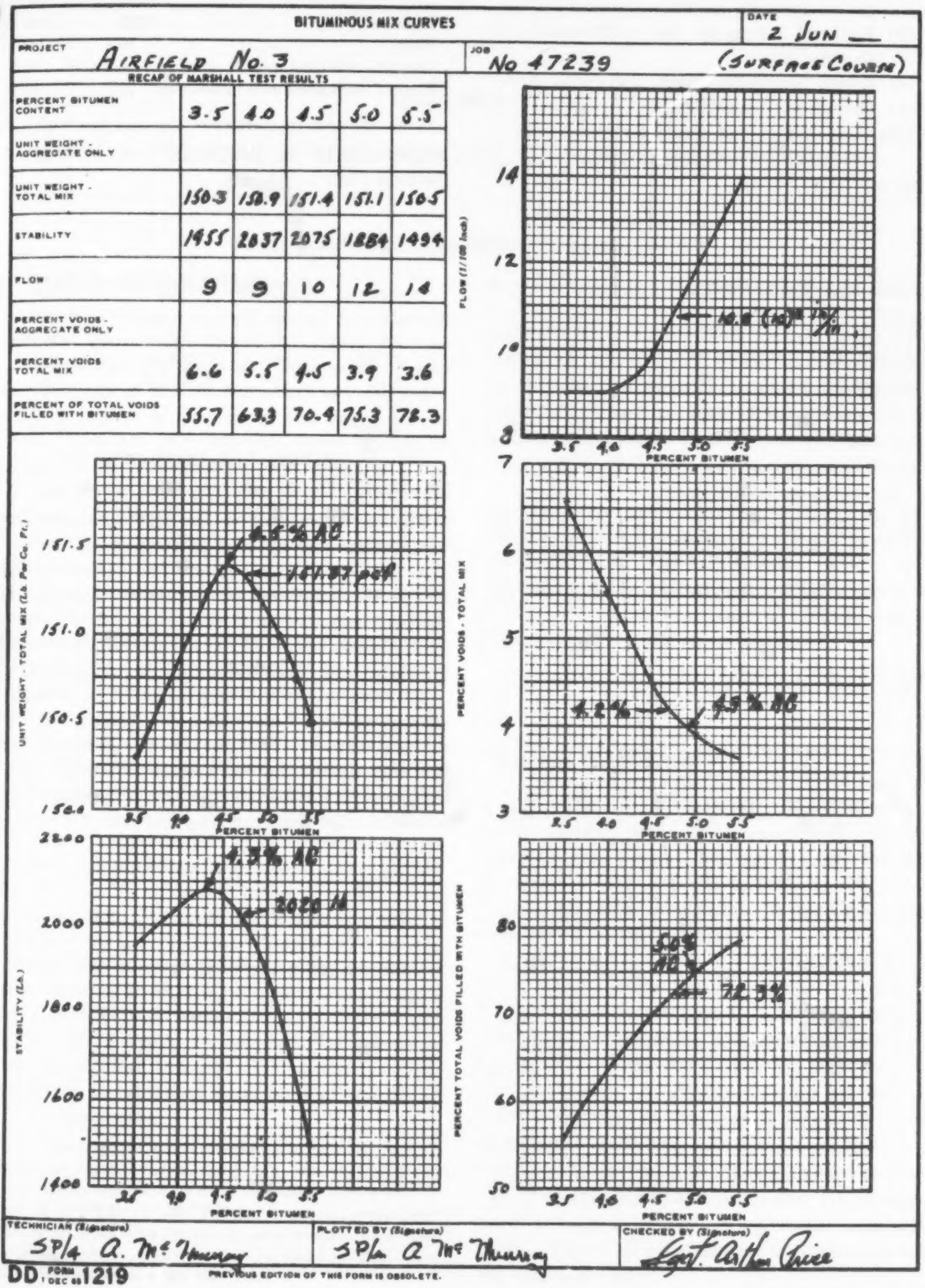
COMPUTED BY SP/4 Alexander Mc Murray

CHECKED BY Sgt. Arthur Price

DD FORM 1 DEC 65 1218

PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

Figure 5. Continued.



BITUMINOUS MIX CURVES

DATE: 2 JUN ___

PROJECT: AIRFIELD No. 3

JOB: No 47239 (SURFACE COURSE)

RECAP OF MARSHALL TEST RESULTS

PERCENT BITUMEN CONTENT	3.5	4.0	4.5	5.0	5.5
UNIT WEIGHT - AGGREGATE ONLY					
UNIT WEIGHT - TOTAL MIX	150.3	150.9	151.4	151.1	150.5
STABILITY	1955	2037	2075	1884	1494
FLOW	9	9	10	12	14
PERCENT VOIDS - AGGREGATE ONLY					
PERCENT VOIDS TOTAL MIX	6.6	5.5	4.5	3.9	3.6
PERCENT OF TOTAL VOIDS FILLED WITH BITUMEN	55.7	63.3	70.4	75.3	78.3

FLOW (1/100 Inch)
8
10
12
14
10.8 (10) 1/100 in.
3.5
4.0
4.5
5.0
5.5
PERCENT BITUMEN
UNIT WEIGHT - TOTAL MIX (Lb. Per Cu. Ft.)
150.0
150.5
151.0
151.5
4.5% AC
151.37 pcf
3.5
4.0
4.5
5.0
5.5
PERCENT BITUMEN
PERCENT VOIDS - TOTAL MIX
3
4
5
6
7
4.2%
4.5% AC
3.5
4.0
4.5
5.0
5.5
PERCENT BITUMEN
STABILITY (Lb.)
1400
1600
1800
2000
2200
4.3% AC
2020 lb
3.5
4.0
4.5
5.0
5.5
PERCENT BITUMEN
PERCENT TOTAL VOIDS FILLED WITH BITUMEN
50
60
70
80
5.0% AC
72.3%
3.5
4.0
4.5
5.0
5.5
PERCENT BITUMEN

TECHNICIAN (Signature)	PLOTTED BY (Signature)	CHECKED BY (Signature)
SP/4 A. McMurray	SP/4 A McMurray	Capt. Arthur Price

DD FORM 1 DEC 65 1219 PREVIOUS EDITION OF THIS FORM IS OBSOLETE.

Figure 9. Bituminous Mix Curves (DD Form 1219), summary of design test properties.

(2) If any one of the curves yields a bitumen out of line with the others, rerun this test.
(3) Recheck aggregate for conformance to specified blend.
(4) Rerun Marshall—check apparatus first.
(5) Change aggregate blend.

Example: Check the trial OBC determined above for conformance to specifications.

Solution:

Test property	*Value* *Actual*	 *Desired*
Stability	2020.	1800. +
Flow	10.8	16. –
Percent voids total mix	4.2	3–5
Percent voids filled with bitumen	72.3	70–80

Since the test properties of the mix are within the specification limits, the trial OBC can be designated the final OBC.

Section IV. JOB MIX FORMULA

33. Job Mix Formula Calculation

After the OBC and aggregate blend have been established, it is necessary to determine the actual percentages by weight of these components in the final mix. These percentages by weight are called the job mix formula. The method of determining this formula is presented by the following example:

Example: The OBC has been set at 5.5 percent. The aggregate blend is 40/30/25/5 (CA/FA/FRBS/LSD). Determine the job mix formula.

Solution:

Percent of mix =

$$\left(\frac{\text{100-percent of bitumen}}{100}\right) \times \text{percent of aggregate}$$

$$\frac{\text{100-percent of bitumen}}{100} = \frac{100\text{-}5.5}{100} = \frac{94.5}{100} = 0.945$$

Component	*Percent of aggregate*	$\frac{\textit{100-percent of bitumen}}{\textit{100}}$	*Percent of mix*
CA	40	x 0.945	37.8
FA	30	x 0.945	28.4
FRBS	25	x 0.945	23.6
LSD	5	x 0.945	4.7
AC	--	------	5.5
Total			100.0

Note. The total percent of mix is always equal to 100.

34. Field Check of Job Mix Formula

The mix is checked in the field for conformance to specifications by two different methods.

a. Mix Percentage Check. The percent of bitumen in the completed mix should be compared with the percentage set up in the design. This should be done at least once daily either at the plant or construction site. See TM 5–530 for procedure.

b. Density Check. The density check is made on samples secured from compacted, cooled, and completed pavement. This test not only checks the mix, but also checks the construction methods used in placing and compacting the mix. The density test is discussed in detail in paragraph 128.

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CHAPTER 5

EQUIPMENT USED FOR BITUMINOUS OPERATIONS

Section I. PRODUCTION EQUIPMENT

35. Asphalt Central Mix Plants

a. Introduction. An asphalt central mix plant is a series of pieces of equipment designed to produce a bituminous plant mix from a bitumen and stockpiled aggregate. The characteristics and number of the pieces of equipment can vary; but in general, there are two principal types of central mix plants—the intermediate-type plant and the high-type plant. Although both plants will handle either asphalt, straight asphalt cement is preferred for use with the high-type plant and cutback asphalts are preferred with the intermediate-type plant. For the production of hot mixes, the use of cutback asphalts should be restricted to those that are slower setting due to the fire and explosion hazards created by the larger amount of more flammable solvents contained in the faster setting products. Both type plants are capable of producing cold mixes. A straight asphalt cement mix must be laid hot shortly after manufacture. Cutback asphalt cement mixes can be laid at longer periods after manufacture, depending upon the amount of cutterstock in the product used. The two principal central mix plants are the 80- to 120-tons-per-hour (TPH) plant and the 10- to 30-TPH plant. A third type of mixing plant, the travel plant, uses components of the 80- to 120-TPH set. Components of the 10- to 30-TPH intermediate-type plant are procurable as separate line items; this plant is not part of the 80- to 120-TPH paving set. Appendix I and DA Pam 310-4 should be consulted for references on operation. SM 5-4-3895-S01 contains a complete list of the standard equipment of the 80- to 120-TPH paving set.

Note. These plants are undergoing changes and will no longer be procured for issue. They will, however, remain in use, but where applicable will be converted from steam to hot oil. A new 100- to 150-TPH plant without travel plant capability is in planning for future procurement. This plant and related support equipment will be listed in TOE's and procured and issued as single line items.

b. Erection. Central plants may be erected on either a hasty or deliberate basis. The difference between these two types of layouts is not in the degree of planning but in the choice of datum planes for ground level. Elevator wells with their attendant safety hazards are avoided in the deliberate layout, although piers of some nature must be constructed for the legs.

Caution: Do not extend the jack legs to their full length to try to overcome the need for piers. In this position, the legs are longer than their safe length and might buckle.

Concrete should be used to construct piers and footers, although timbers such as railroad ties may be used as expedients.

Note. Detail drawings of the recommended plant layouts for various combinations of the 80- to 120-TPH paving set are contained in TM 5-337-1.

36. Selection of Central Plant Site

a. General Location. The general location of a central plant should be as close as possible to the source of aggregate, yet be within a short hauling distance of the project. Most plant mixes will either become too cool or begin to cure if they are not placed soon after production. A good road net is necessary to avoid traffic jams.

b. Specific Location. The specific location of a central plant should be in a well-drained location. The site must have room to maneuver equipment and stockpile materials. Drummed asphalt should be stored a safe distance from the plant to reduce the fire hazard. A sidehill location not only improves drainage but also greatly reduces the explosion hazard associated with loading trucks in a pit. Should it be necessary to locate the plant on a level site for other reasons, the loading pit should be made as large as possible to allow maximum ventilation. Figure 10 demonstrates the hazard of loading trucks in a pit.

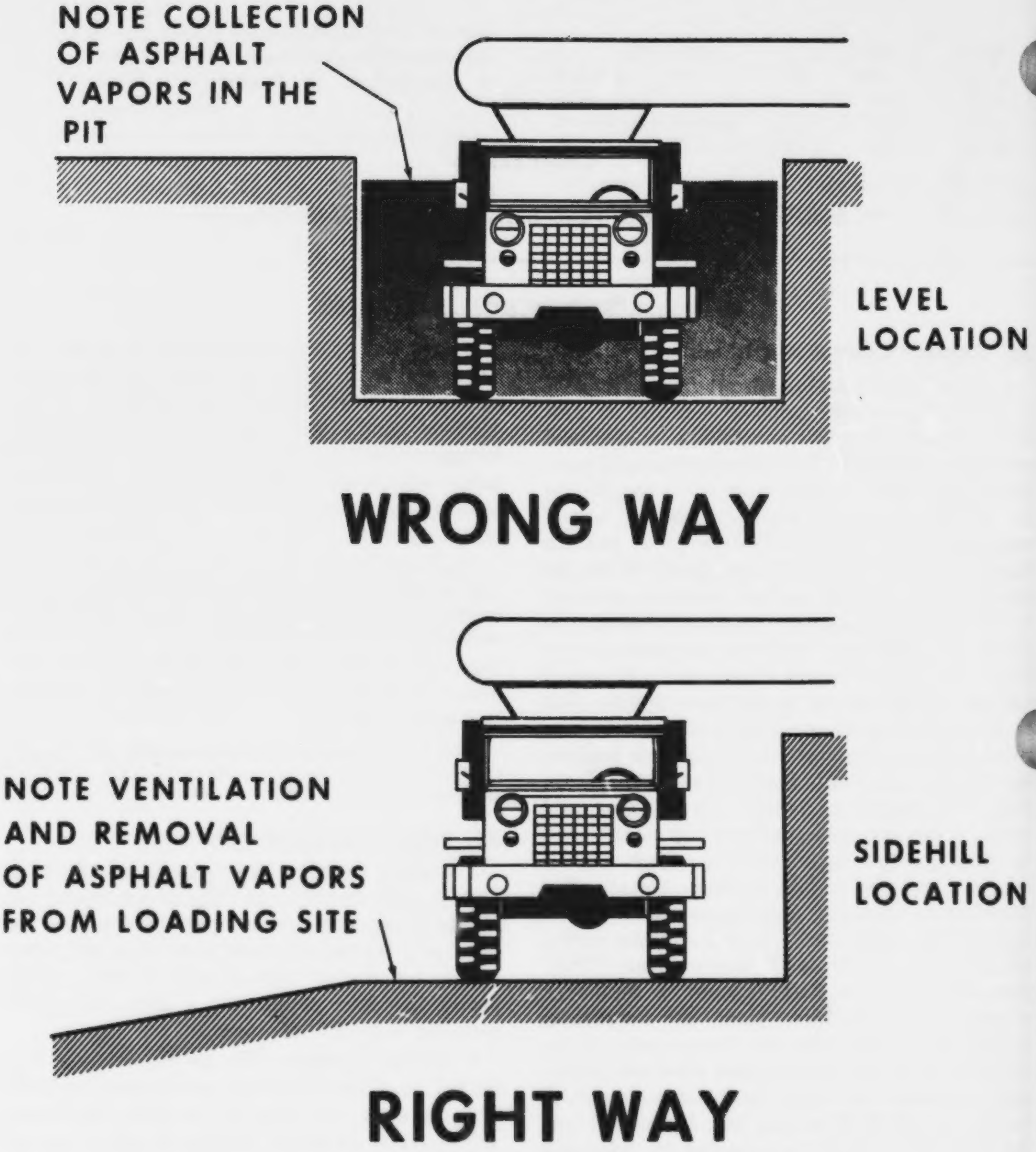
NOTE COLLECTION OF ASPHALT VAPORS IN THE PIT
LEVEL LOCATION
WRONG WAY
NOTE VENTILATION AND REMOVAL OF ASPHALT VAPORS FROM LOADING SITE
SIDEHILL LOCATION
RIGHT WAY

Figure 10. Proper central plant location to avoid explosion hazard.

37. The 80- to 120-TPH Paving Set

The 80- to 120-TPH paving set is the largest asphalt plant in the Army supply system. It is capable of producing all types of bituminous mixes including high-type asphaltic concrete, cold mixes, and stabilized base mixtures. The separate units that make up the set may be arranged in three basic combinations to produce a variety of mixes. The choice of arranging the set as a high-type, intermediate-type, or travel plant will depend upon the necessary operations to produce the required mix. The travel plant is discussed in paragraph 39.

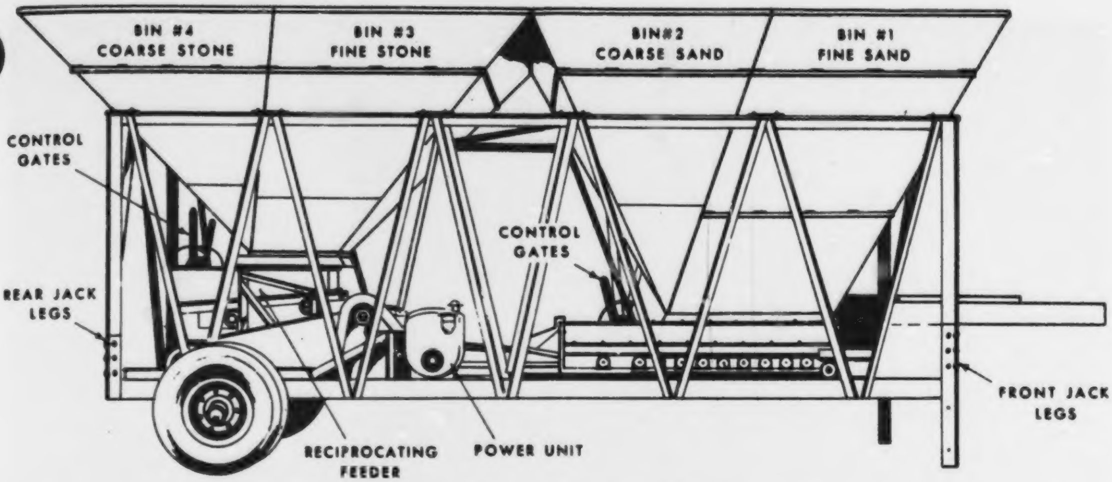
BIN #4
COARSE STONE
BIN #3
FINE STONE
BIN #2
COARSE SAND
BIN #1
FINE SAND
CONTROL GATES
CONTROL GATES
REAR JACK LEGS
FRONT JACK LEGS
RECIPROCATING FEEDER
POWER UNIT

Figure 11. Four-bin cold aggregate feeder, 80- to 120-TPH set.

a. Component Units. The units comprising he 80- to 120-TPH plant are summarized in table IV, and are described below.

(1) *Feeder* (fig. 11). The feeder unit is of the reciprocating type, and has two bins to accommodate both fine and coarse aggregate. It receives aggregate from the belt conveyor, feeding it into the first elevator for transmission to the dryer. The feeder is included in specifications as a component of the dryer. A four-bin feeder is also issued with the set and used in lieu of the reciprocating feeder.

(2) *First elevator (Model 881 cold elevator)* (fig. 12). The first elevator is an open bucket type cold elevator, 18 feet 3 inches, center-to-center. It is shaft and gear driven, and is equipped with a pneumatic-tired dolly for portability. It is used to move aggregate from the feeder to the aggregate dryer. It, too, is included in specifications as a component of the dryer.

(3) *Model 837 aggregate dryer* (fig. 13). The aggregate dryer is trailer-mounted and provided with retractable jack legs to eliminate the need for cribbing the unit while in operation. The dryer is the single drum type, and is diesel powered. Its purpose is to remove moisture from the aggregate and to heat the aggregate to any desired temperature. Heat is supplied to the dryer by a low pressure oil burner.

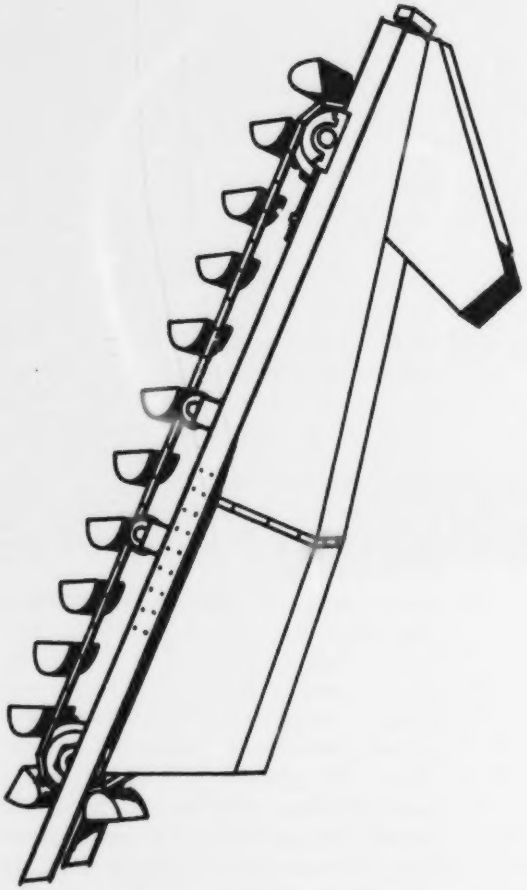

Figure 12. Model 881 cold elevator, 80- to 120-TPH set.

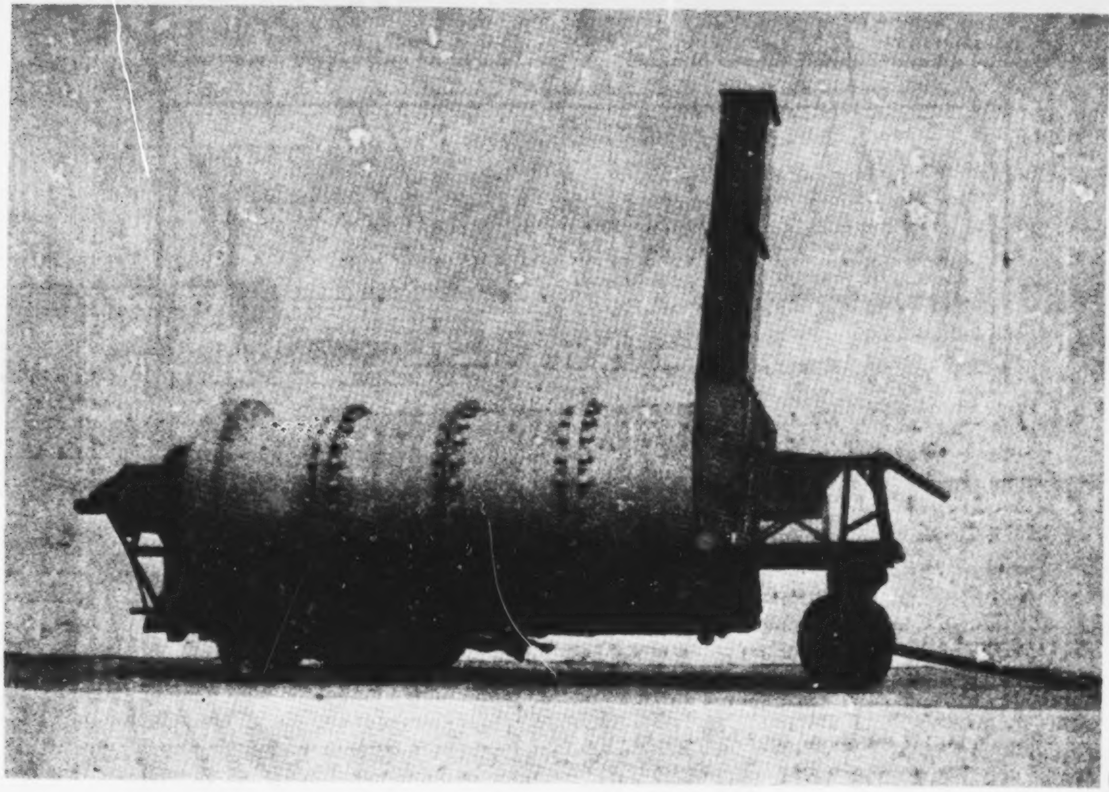

Figure 13. Model 837 aggregate dryer, 80- to 120-TPH set.

(4) *Model 857 dust control unit* (fig. 14). The dust control unit (dust collector) is used in connection with the dryer to reclaim fines from the exhaust gases and to reduce the dust nuisance. Fines from the dust collector are delivered by a screw feeder to the second elevator if additional fines are needed, or wasted if sufficient fines are available within the mix.

(5) *Second elevator (Model 830 hot elevator)* (fig. 15). This elevator is an enclosed bucket type elevator, 27 feet 6 inches, center-to-center. Usually, a 21-foot 9-inch elevator is modified with a 5-foot 9-inch elevator extension to produce this long elevator. The elevator is provided with a pneumatic-tired dolly for portability, and is shaft and gear driven. The second elevator is used to move aggregate from the dryer to the gradation control unit. The fines from the dust control unit are also fed into this elevator for delivery to the gradation control unit.

(6) *Model 866 gradation control unit* (fig. 15). The gradation control unit is also trailer-mounted and jack-leg equipped. It is provided with a four-compartment bin and suitable vibrating screens to separate the dried aggregate according to size. The unit feeds proper proprotions of various sizes of aggregate into the third elevator for delivery to the mixer.

(7) *Third elevator (Model 880 hot elevator)* (fig. 16). The third elevator is similar to the second elevator, but is 18 feet 3 inches, center-to-center. It is used to deliver the graded aggregate from the gradation control unit and the fines feeder to the asphalt mixer.

(8) *Fines feeder.* The fines feeder is provided with a screw conveyor. It is used to supply very fine aggregate to the third eleva-

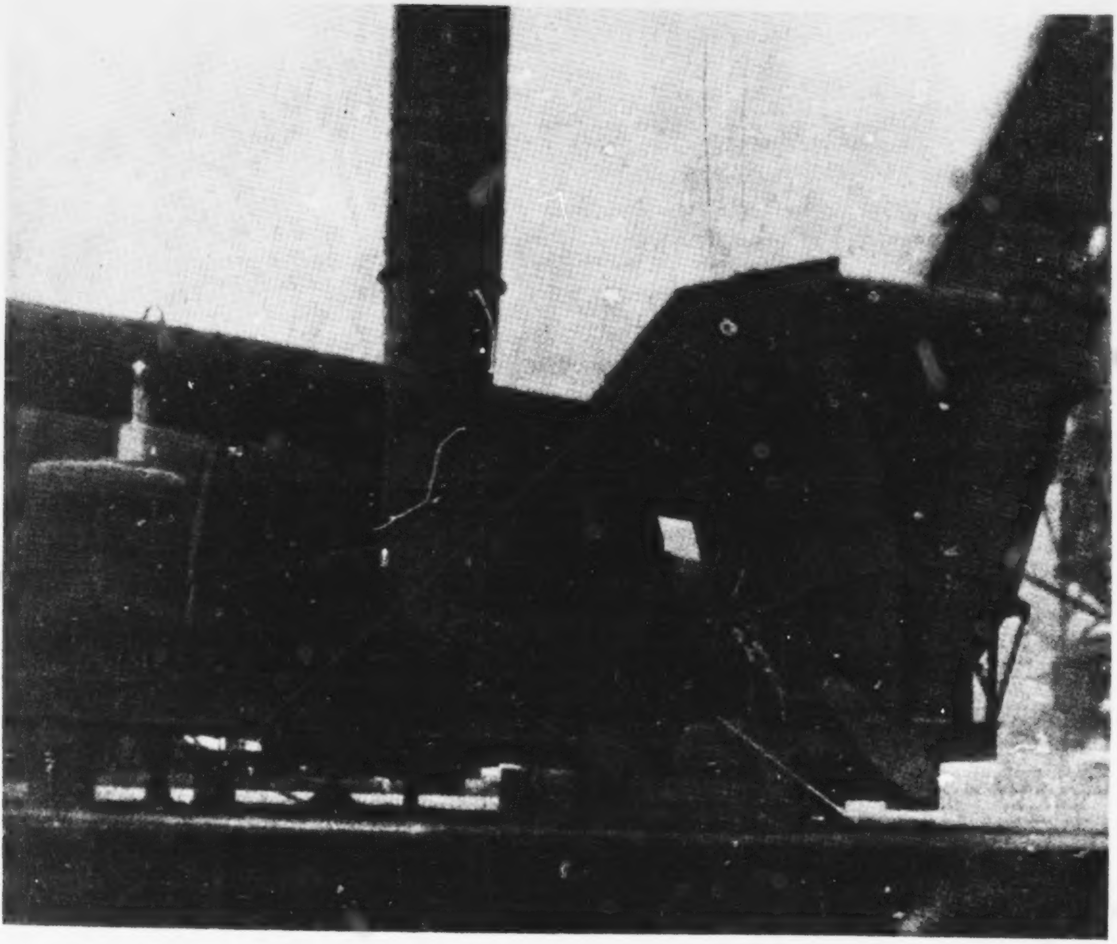

Figure 14. Model 857 dust control unit, 80- to 120-TPH set.

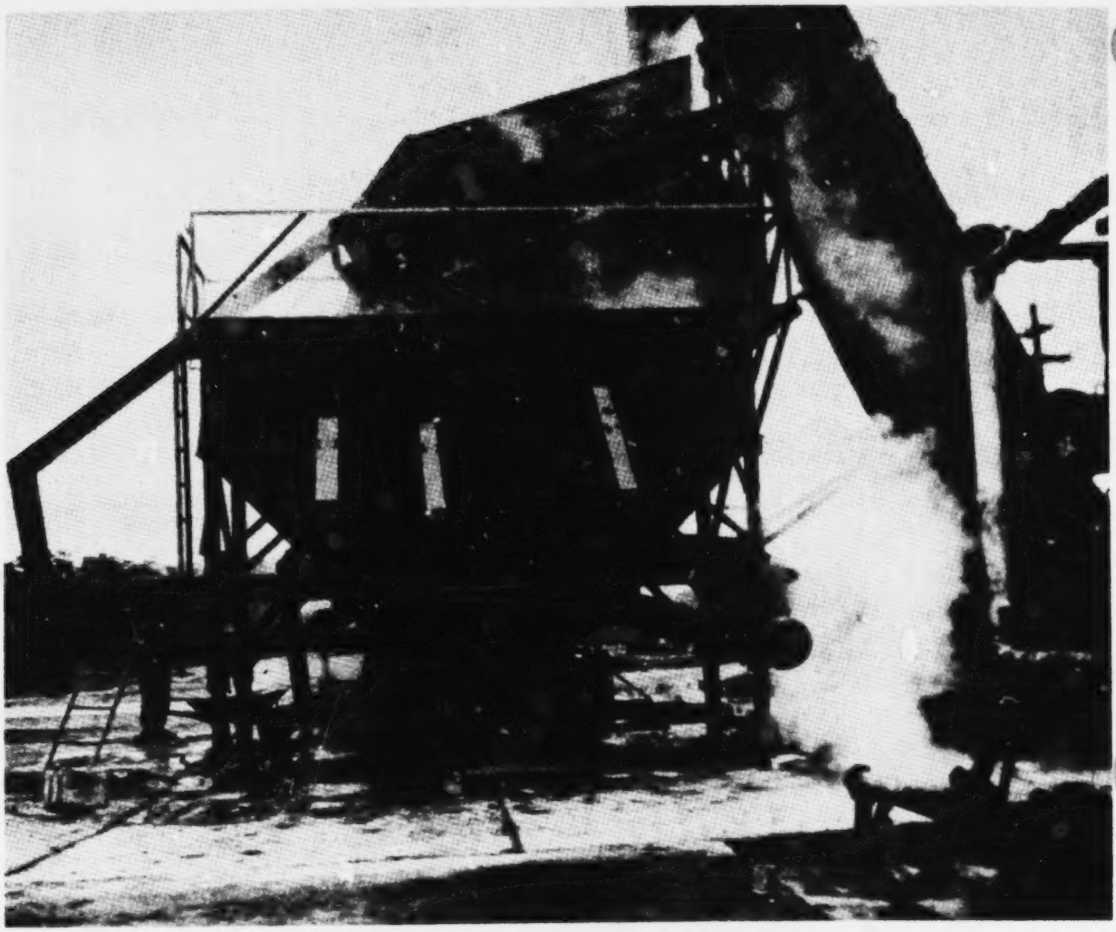

Figure 15. Model 866 gradation control unit with Model 880 hot (second) elevator on right, 80- to 120-TPH set.

tor, thereby supplementing the operation of the gradation control unit.

(9) *Model 848 asphalt mixer* (fig. 16). The asphalt mixer is the unit which actually combines bitumen with graded aggregate to produce a bituminous hot mix. The mixer is trailer mounted and is cribbed when the unit is in operation. The mixer is diesel driven. Necessary heat for the hot mixing operation is supplied from either a hot oil system or a steam plant. Components of the mixer are a bitumen tank, a bitumen metering pump, a twin pugmill and a discharge control gate. The mixer normally discharges the finished material directly into trucks for delivery to the job site.

(10) *Heating plant.* Heat is supplied to the dryer, the mixer, and the storage tanks by either a steam boiler plant or a hot oil system. The older models have the steam plant; the newer models have a hot oil system.

(11) *Storage tanks.* The asphalt storage tanks are of bolted steel construction. They are provided with coils to heat the contained bitumen, the heat being supplied from an external source. Each tank has a capacity of 4,000 gallons, and four such tanks is a normal complement for a single central mix plant. The tanks are not trailer

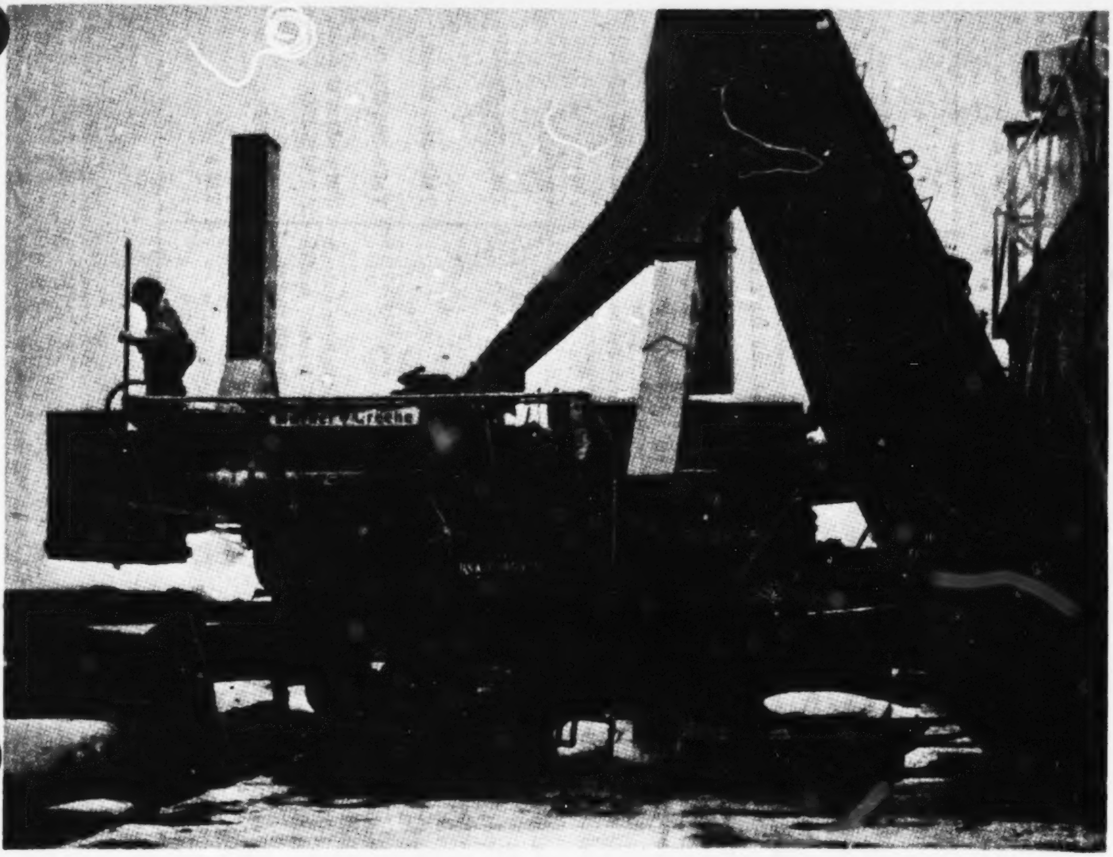

Figure 16. Model 848 mixer with Model 880 hot (third) elevator on right, 80- to 120-TPH set.

mounted. They must be disassembled for transporting.

(12) *Piping equipment.* This equipment includes the bitumen and either hot oil or steam pipes necessary to set up the plant.

b. 80- to 120-TPH High-Type Plant. The 80- to 120-TPH high-type plant is equipped with a gradation control unit to control gradation of the aggregate as it comes from the stockpile. The gradation control unit provides the means of producing a high-type bituminous concrete, thus the name high-type plant. The high-type central plant is capable of producing a high quality hot mix that will conform to the most rigid specifications for both roads and airfields. A schematic diagram of the material flow is shown in figure 17. A typical setup of the 80- to 120-TPH high-type plant is depicted in figure 18.

c. 80- to 120-TPH Intermediate-Type Plant. The intermediate-type central mix plant is identical to the 80- to 120-TPH high-type plant except that this plant is not equipped with the gradation control unit. For this reason, aggregate gradation in the stockpile must be more rigidly controlled. In the intermediate-type plant, an aggregate hopper and apron feeder are attached to the mixer to proportion the aggregate. Because gradation of the aggregate is not as rigidly controlled, the intermediate-type plant is suitable for producing cold-laid mixes or hot mixes for road construction or repair work, but not for airfield construction. However, it can construct a better runway than the travel plant. Figure 19 is a schematic diagram of the material flow in this plant. A typical 80- to 120-TPH intermediate-type plant is shown in figure 20.

Table IV. *Components of the 80- to 120-TPH Paving Set.*

Unit	Description	Model number	Number required	Purpose	Component of		Remarks	Related manual
					High-type	Inter-mediate-type		
1	Feeder, reciprocating, or four-bin.	813 or 815	1	To feed aggregate to first elevator.	x	x	Specs include this as a component of the dryer.	TM 5-1011—if four-bin hopper is used, TM 5-1376.
2	First elevator (cold elevator).	881	1	To deliver aggregate from feeder to dryer.	1, 2	1, 2	This also included as a component of the dryer.	TM 5-1011
3	Aggregate dryer	837	1	To remove moisture from aggregate, and to heat aggregate to desired temp.	x	x		TM 5-1011
4	Dust control unit	857	1	To reclaim fines from dryer exhaust gases; to reduce dust nuisance.	x		This also included as a component of the dryer.	TM 5-3895-243-10
5	Second elevator (hot elevator).	880	1	To move aggregate from dryer and dust control unit to gradation control unit.	1, 2	1	Height increased by use of standard accessories.	TM 5-3910-200-12P
6	Gradation control unit.	866	1	To control gradation of aggregates in bituminous mix.	x			TB 5-1109-1
7	Third elevator (hot elevator).	880	1	To deliver aggregate from the gradation control unit and the fines feeder to the mixer.	1, 2			TM 5-3910-200-12P
8	Fines feeder	811A	1	To introduce fines to the third elevator.	x			TM 5-3895-208-10
9	Asphalt mixer	848	1	To combine bitumen and aggregate into a bituminous hot mix.	x	3		TM 5-3895-208-10
10	Heating plant		1	To supply heat to the various units of the asphalt plant.	x		Older models have a steam plant. Newer models have a hot oil system.	TM 5-650, TM 5-651, TM 5-5243
11	Storage tanks, 4,000 gallon.	---	4	To store bitumen for continued operation of plant.	x	x		TM 5-1016
12	Piping equipment	---	1 set	To connect bitumen tanks and steam plant to other units of plant.	x	x		TM 5-1016

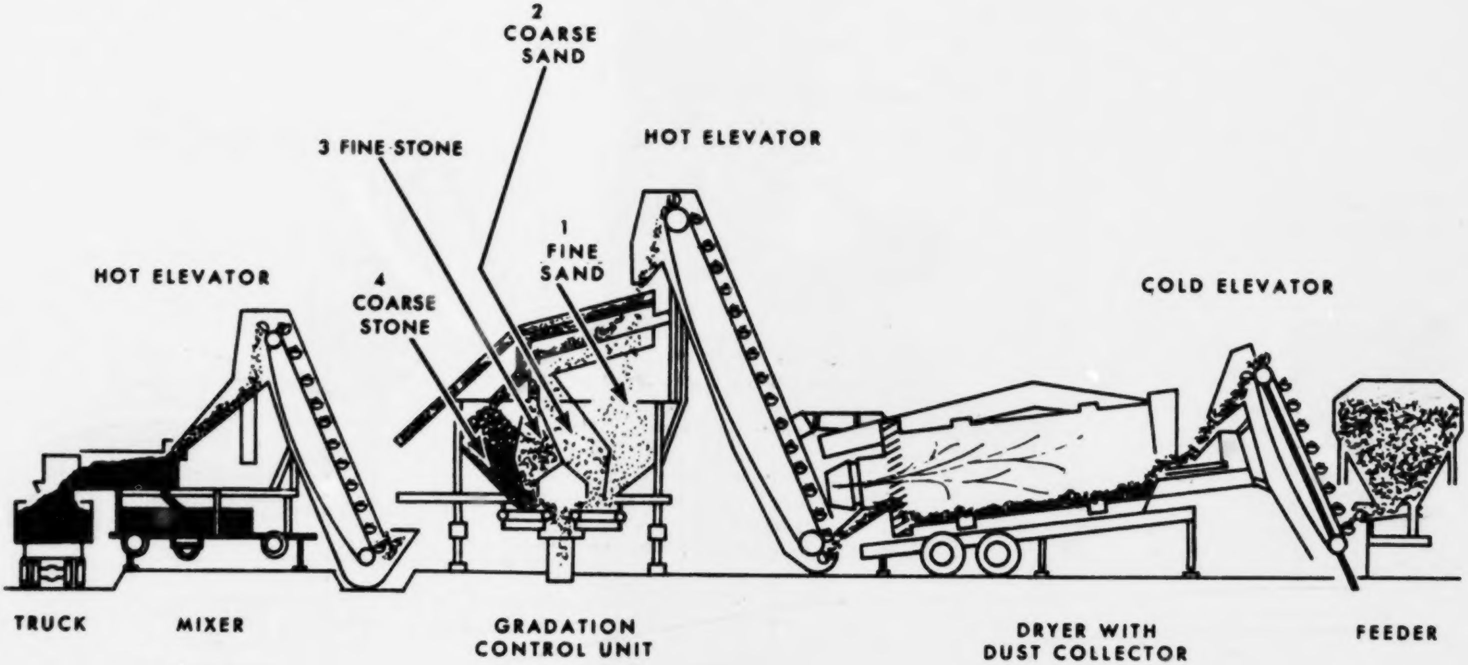
2
COARSE
SAND
3 FINE STONE
HOT ELEVATOR
1
FINE
SAND
HOT ELEVATOR
4
COARSE
STONE
COLD ELEVATOR
TRUCK
MIXER
GRADATION
CONTROL UNIT
DRYER WITH
DUST COLLECTOR
FEEDER

Figure 17. Schematic diagram of the 80- to 120-TPH high-type plant.
(From "Bituminous Construction Handbook," courtesy of Barber-Greene Company.)

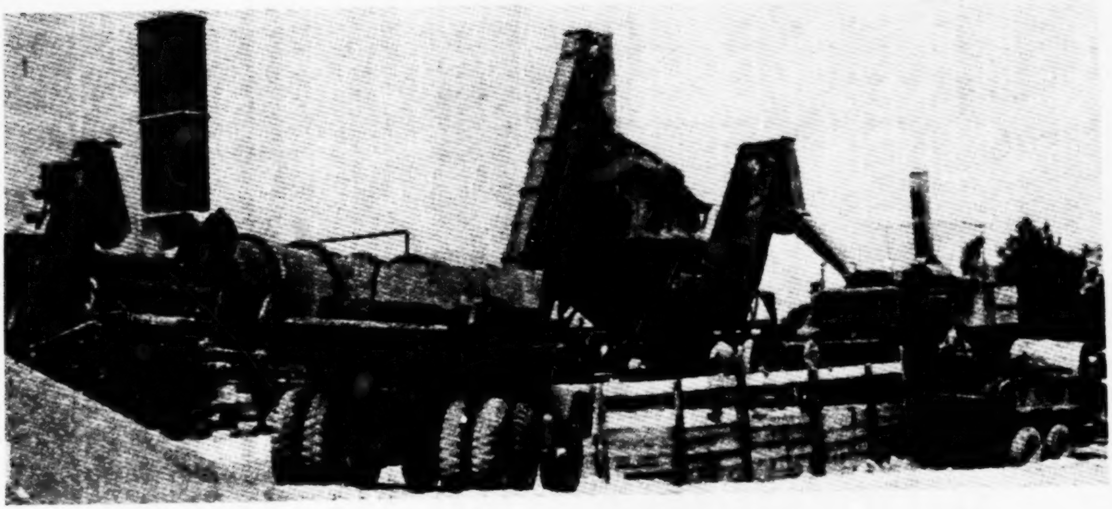

Figure 18. Typical 80- to 120-TPH high-type plant.

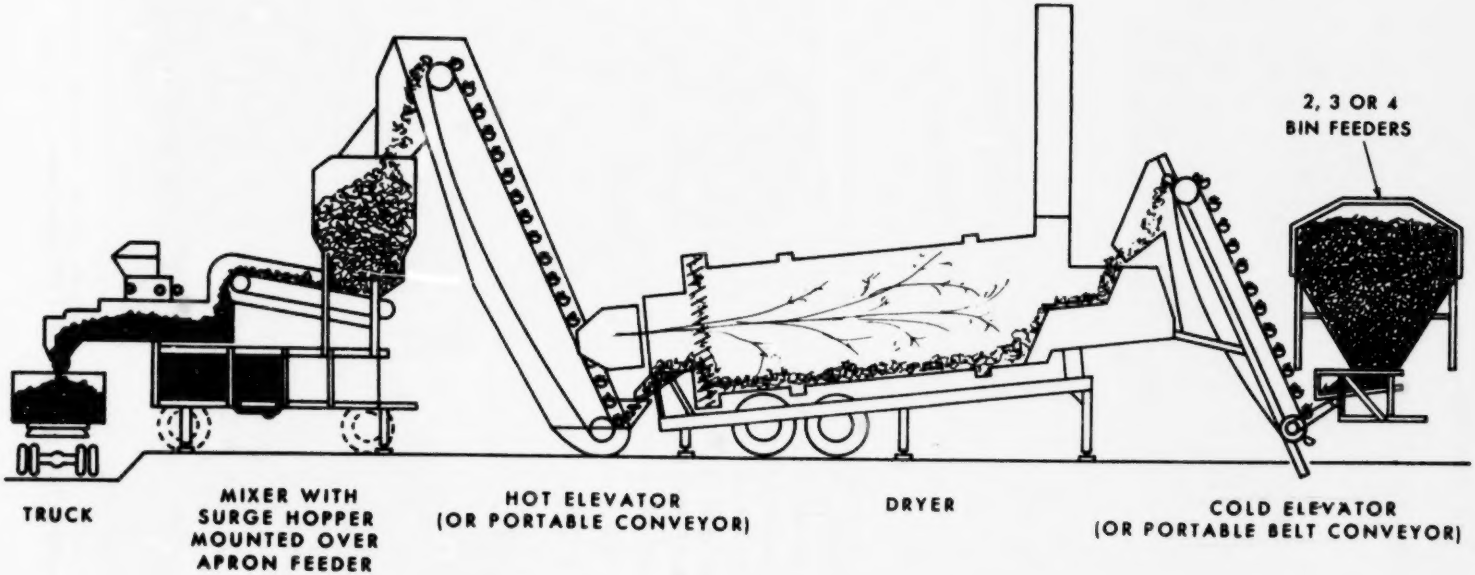
2, 3 OR 4 BIN FEEDERS
TRUCK
MIXER WITH SURGE HOPPER MOUNTED OVER APRON FEEDER
HOT ELEVATOR (OR PORTABLE CONVEYOR)
DRYER
COLD ELEVATOR (OR PORTABLE BELT CONVEYOR)

Figure 19. Schematic diagram of the 80- to 120-TPH intermediate-type plant.

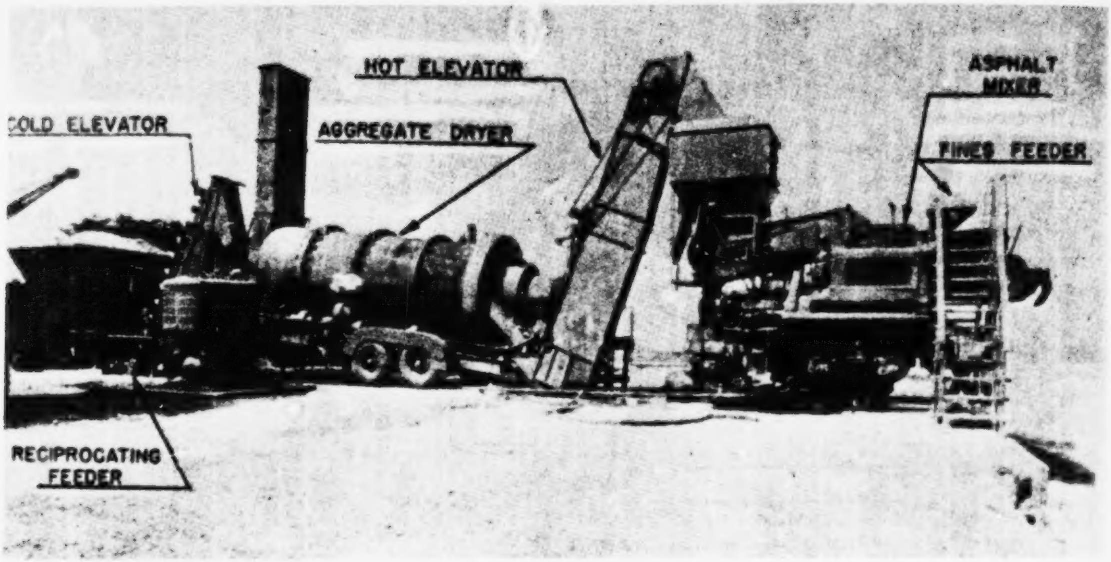
HOT ELEVATOR
ASPHALT MIXER
COLD ELEVATOR
AGGREGATE DRYER
FINES FEEDER
RECIPROCATING FEEDER

Figure 20. Typical 80- to 120-TPH intermediate-type plant.

38. The 10- to 30-TPH Asphalt Plant

a. Introduction. The 10- to 30-TPH asphalt plant (fig. 21) is a small intermediate-type plant for projects whose total job requirements will be less than 10,000 cubic yards of plant mix. The plant may be arranged in only one basic combination to produce intermediate-type hot and cold mixes and stabilized base mixtures.

b. Component Units. The units comprising the 10- to 30-TPH asphalt plant are similar in detail to the components of the 80- to 120-TPH paving set (par. 37) except that the individual units have a much smaller capacity. Instructions for the operation of all components of the 10- to 30-TPH asphalt plant are contained in TM 5–1281–1. Figure 22 depicts a schematic diagram of the 10- to 30-TPH asphalt plant.

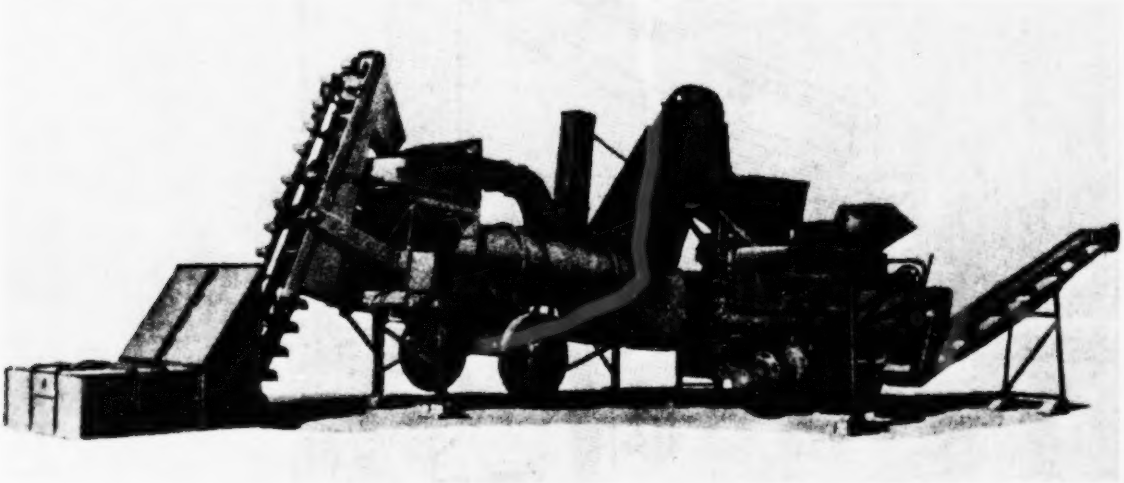

Figure 21. Typical 10- to 30-TPH asphalt plant.

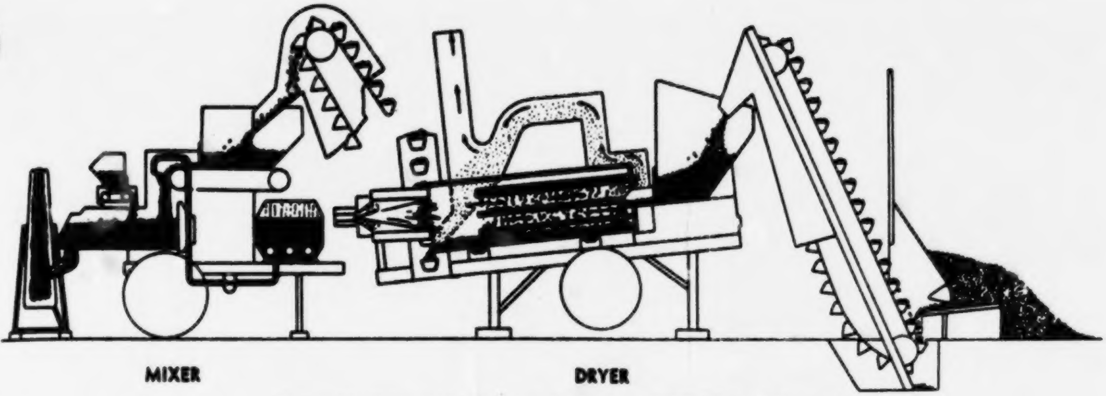

Figure 22. Schematic diagram of the 10- to 30-TPH asphalt plant.

39. Travel Plant

a. Standard Travel Plant. The standard travel plant comprises the Model 848 mixer from the 80- to 120-TPH paving set and the crawler mounted aggregate elevator (bucket loader) (fig. 23). The Model 848 mixer is discussed in paragraph 37*a*(9). The bucket loader consists essentially of a crawler mounted tractor unit and a boom. The boom consists of a metal spiral charger that delivers material to a bucket line which elevates the material. A scraper unit behind the spirals aids in the clean pickup of material. The crawler section supports the boom and provides power for the operation of the bucket line. The bucket loader also provides the motive power for the mixer unit. Three asphalt tanks are necessary to supply the bitumen. Table V summarizes the units of the standard travel plant. Figure 24 shows a schematic view of a standard travel plant.

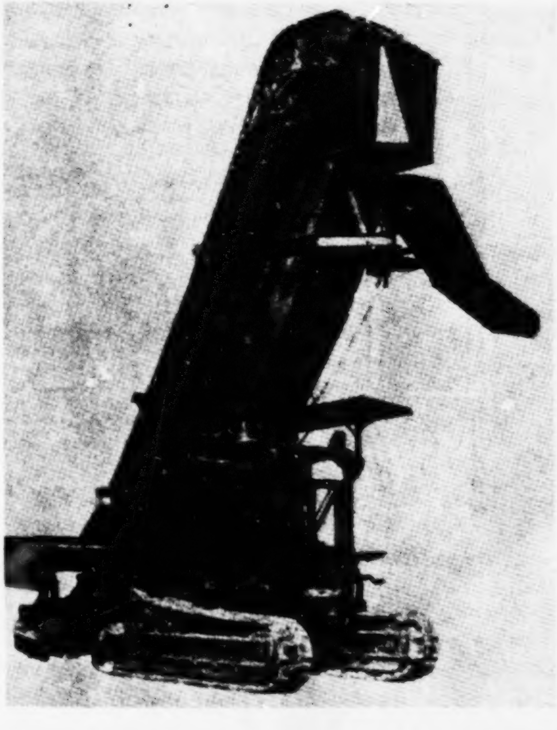

Figure 23. Crawler mounted aggregate elevator (bucket loader).

Note. The bucket loader will be replaced by a scoop (end) loader concurrently with phasing out of the Model 848 mixer.

Table V. Equipment Used in the Travel Plant

Equipment	Number of units	Purpose
Aggregate elevator (bucket loader).	1	Pick up aggregate from window and deliver it to mixer hopper.
Asphalt mixer --------	1	Mix bitumen and aggregate correctly and combine them in a thorough bituminous mixture.
Trailer-mounted asphalt tank, 1,500 gal.	1	Supply material to bitumen tank of mixer.
Truck-mounted asphalt tank, 800 gal.	1	Transport material from central storage tanks to trailer mounted asphalt tank.
Asphalt tank, 4,000 gal. -	1–2	Stone enough asphalt for sustained mixer operation.

b. Expedient Travel Plants. A properly adjusted rotary tiller will yield a mix of slightly lower quality than that from a standard travel plant. The rotary tiller is a tractor type vehicle with a mixing

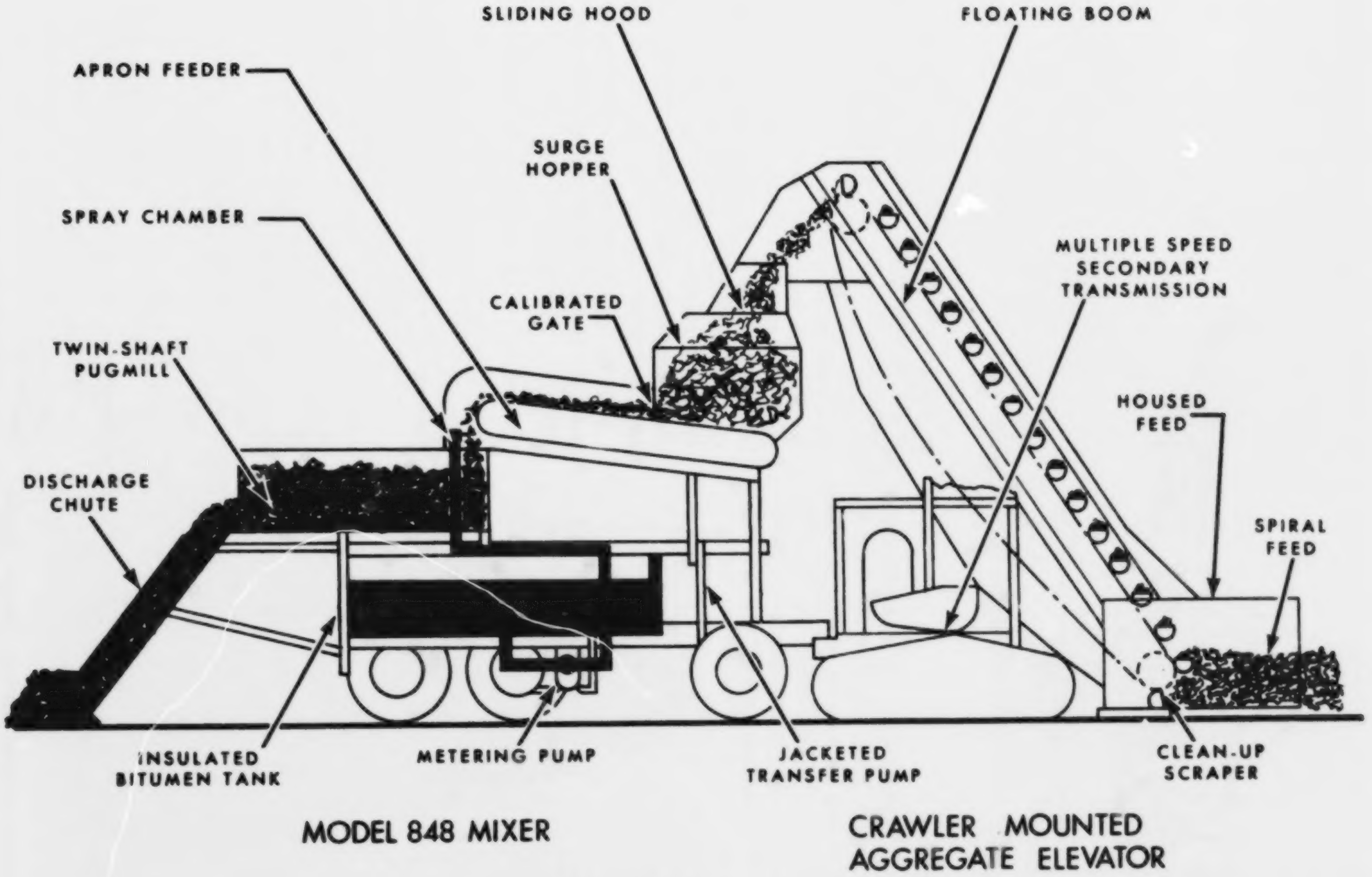
SLIDING HOOD
FLOATING BOOM
APRON FEEDER
SURGE HOPPER
SPRAY CHAMBER
MULTIPLE SPEED SECONDARY TRANSMISSION
CALIBRATED GATE
TWIN-SHAFT PUGMILL
HOUSED FEED
DISCHARGE CHUTE
SPIRAL FEED
INSULATED BITUMEN TANK
METERING PUMP
JACKETED TRANSFER PUMP
CLEAN-UP SCRAPER
MODEL 848 MIXER
CRAWLER MOUNTED AGGREGATE ELEVATOR

Figure 24. Schematic view of a standard travel plant.
(From "Bituminous Construction Handbook," courtesy of Barber-Greene Company.)

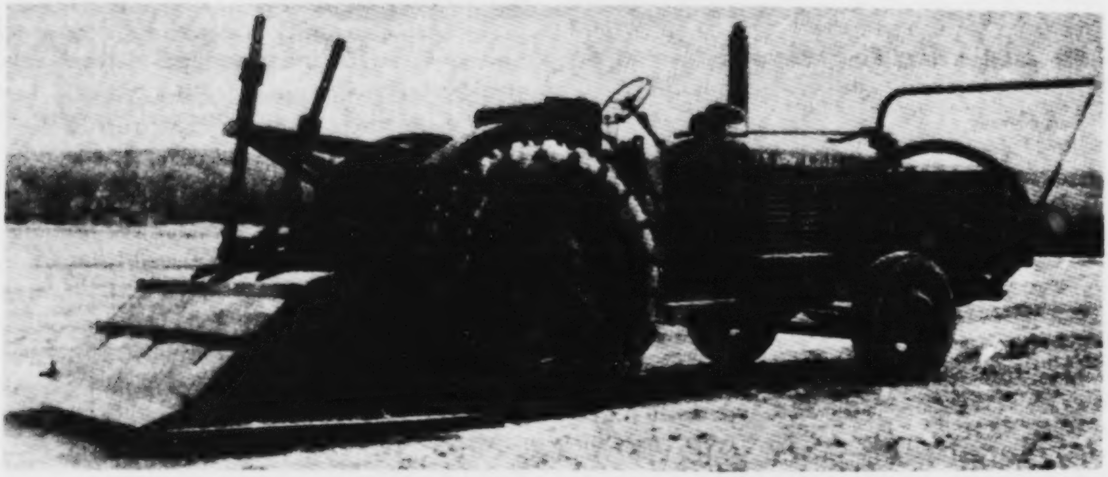

Figure 25. Rotary tiller with a pump.

device attached to the rear. Some models have a pump on the front. The mixing device is a series of rotating vanes on a shaft under an enclosed hood. Figure 25 shows a rotary mixer with a pump. Disk harrows and motor graders may also be used to produce low quality road mixes.

c. Operating Features. The standard travel plant may be used in tandem with an asphalt finisher provided windrow sizes are small enough to be within the capacity of the paver.

40. Choice of Type of Plant

Specifications calling for a high-type mix allow no choice of plant; a high-type plant (80- to 120-TPH) must be used. Specifications calling for an intermediate-type mix or stabilization mix leave the project supervisor with three plant choices: the 80- to 120-TPH plant, the 10- to 30-TPH plant, and the travel plant. The travel plant cannot be used for hot mixes but it is more economical, permits maximum equipment output, handles in place aggregate with little supporting help, and is simple to use. The two central plants can mix hot, cold, and stabilization mixes; are better adapted to damp weather operations; are capable of day and night operations; and keep bulky equipment off of subgrades. However, central plants require additional handling of aggregate. Long distances between plant site and project are not recommended for hot mixes and rapid curing cold mixes. If high-type mixes are not to be produced, production capacity will be the main factor in the choice between the 80- to 120-TPH plant and the 10- to 30-TPH plant. The rated hourly production of these plants will drop greatly under less than ideal conditions. For example, the 80- to 120-TPH plant can produce only about 65 tons-per-hour when the aggregate moisture content is 12 percent. A project calling for a total of more than 10,000 cubic yards of mix should have an 80- to 120-TPH set. The project supervisor should take both the expected hourly production requirements and the overall size of the project into consideration before making a decision upon which type of central plant is to be used.

41. Liquid Handling Equipment

a. Three-Car Heater. The three-car heater is a small portable horizontal fire tube boiler used to generate steam in asphalt operations. It is principally used to heat tank cars of bitumen to facilitate unloading operations. It may also be used as an expedient heat source at central plants. Detailed information concerning the three-car heater may be found in TM 5–1046 and TM 5–1078.

b. 750-Gallon Asphalt Kettle. The 750-gallon asphalt kettle is mounted on skids. The top of this insulated kettle has four large doors through which material may be dropped from 55-gallon drums. Inside this kettle are two U-shaped fire tubes through which heat is applied from burners mounted on one end of the kettle. A small gasoline engine on the other end of the kettle powers a fuel pump, asphalt pump, and an air blower. Conveyor (modified hand) trucks and portable burners are organic parts which ease dedrumming operations. Additional information is contained in TM 5-1147.

Note. Newer plants will use a 750-gallon per hour asphalt melter in lieu of the 750-gallon asphalt kettle.

c. 165-Gallon Asphalt Kettle. The 165-gallon asphalt kettle is primarily used in maintenance work. It is similar in operation to the 750-gallon asphalt kettle. For more information, see TM 5-1154, TM 5-1157, and TM 5-1158.

d. 1500-Gallon Trailer-Mounted Asphalt Tank. The trailer-mounted tank is used to transport, dedrum, or heat bitumens. The insulated tank is fitted with two sets of steam coils for applying heat by means of steam or hot oil. Connections at the rear of the tank permit pumping material either in or out of the tank. The top is fitted with barrel rests and hoods for dedrumming. TM 5-1081 gives detailed information on this item.

e. Other Liquid Handling Equipment. The 800-gallon truck mounted distributor can be used as a pump or transporting device. The trailer mounted distributor can also be used as a pump. Both of these items are discussed in paragraph 44.

42. Hauling Equipment

The 5-ton dump truck is standard equipment for hauling aggregate and plant mix in bituminous operations (fig. 26). In hot mix operations, heat may be retained by fixing insulating materials (such as a layer of cardboard) to the sides of the truck and a canvas cover placed on top. Diesel fuel is often used to coat the truckbed before each loading. This facilitates the cleaning of the truck after operations, but contributes another fire hazard. A class II fire point should be located at the diesel spraying station.

43. Support Equipment

In addition to the specialized asphalt equipment, additional support equipment is required in a plant operation. Aggregate handling may include clamshell, belt, conveyor, front loader, or dozer depending on plant location and type of cold aggregate feeder used on plant. Low-bed trailer, truck-mounted crane with barrel sling, and air compressor with drum opening tool are needed to transport, store, and open drums of asphalt cement. Fuel trucks will be required to supply fuel for the hot oil heaters and power plants. If the old steam heating plant is used, water trucks may be needed to supply water for the steam boiler.

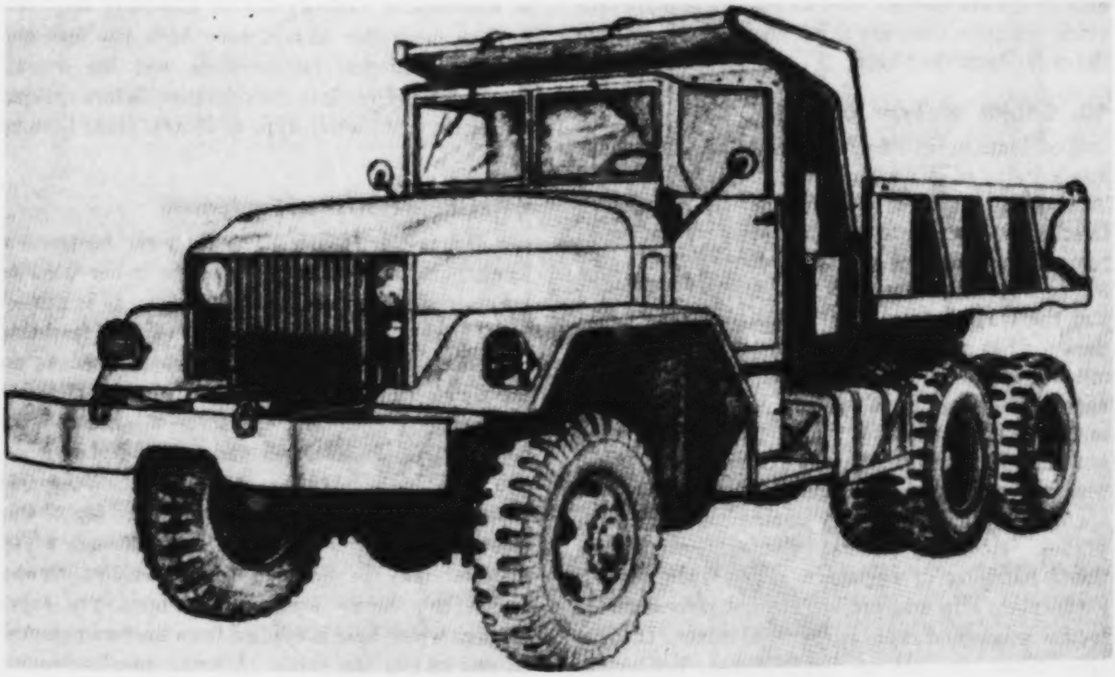

Figure 26. 5-ton dump truck.

Section II. PLACEMENT EQUIPMENT

44. Asphalt Distributors

a. Truck-Mounted Asphalt Distributor. This machine is used primarily to spray bituminous material on a prepared surface. The 800-gallon insulated tank is equipped with heating flues for application of heat from an oil burner. A gasoline engine mounted to the rear of the tank provides power for an asphalt pump, a fuel pump, and air blower. The asphalt pump has a minimum capacity of 375 gallons per minute. Bituminous material is applied through an adjustable length spray bar or a hand spray gun. The spray bar may be of circulating or noncirculating type, depending on the model of distributor. Flow of bituminous material is controlled by a system of hand operated valves. A tachometer registers the pump discharge in gallons per minute. A bitumeter on the truck shows the forward speed of the truck in feet per minute. Figure 27 shows the necessary bitumeter and tachometer readings for given nozzle sizes to obtain the desired rate of bitumen application. Figure 28 shows a truck-mounted asphalt distributor. TM 5-1134, TM 5-3895-201-10, and TM 5-3895-220-15 contain additional information.

b. Tankless Type, Trailer-Mounted Asphalt Distributor. The trailer-mounted distributor (fig. 29) is used in the same manner as the truck-mounted distributor except that it must be accompanied by a mobile source of liquid asphalt such as the 1500-gallon asphalt trailer (para 41*d*). Also it does not have a bitumeter, but the speedometer of the towing vehicle may be used as a reasonably accurate bitumeter. The desired bitumeter reading is multiplied by 0.682 to obtain a miles per hour for use with the speedometer. The 50- to 350-gallons per minute pump may be used for straight asphalt pumping at a central plant. Additional information is contained in TM 5-1130, TM 5-3895-204-10, and TM 5-3895-217-10.

45. Asphalt Finishers (Bituminous Pavers)

a. Model 879-B, asphalt finisher (fig. 30) is the only finisher currently in the Army supply system. This machine is used to lay hot or cold bituminous mixtures into a smooth mat of required thickness and width. Although the finisher is capable of handling up to 200 tons of mix per hour, its effective capacity is 100 tons per hour. The mat width may be varied from 8 to 14 feet, the depth from ½ to 6 inches, and the laydown speed from 12 to 64 feet per minute. The finisher consists essentially of a crawler-mounted tractor unit and a screed unit that is towed by the tractor.. A 5-ton charging hopper is mounted on the front of the finisher where the mix is dumped from a truck. A bar feeder on the hopper floor moves the mix to the spreading screws which spread the mix in front of the screed unit. At the front of the screed assembly, a tamper bar strikes off the mat to desired elevation and compacts it to as much as 85 percent of final density. The screed follows the tamper and irons the tamped surface. An air blower, fuel pump, and burner permit heating of the screed unit before operation or while laying a mat. Thickness of the mat is controlled by two thickness control screws. The screed may be adjusted to produce a crowned mat. Normal width of the screed is 10 feet but the width may be increased to 14 feet by use of screed extensions or reduced to 8 feet by use of cutoff shoes. The finisher is powered by a gasoline engine. Detailed information is contained in TM 5-3895-218-15. Figure 31 shows a schematic view of this finisher.

b. The manually operated dual controls of the Model 879-B finisher allow the operator to sit on the same side of the machine as the guideline or the edge of the existing mat. This feature greatly eases longitudinal joint alinement control. Dual controls are most advantageous for paving in narrow places such as parking areas and around airfield facilities. Operators may be stationed on both sides in such restricted places, greatly reducing the chance of collision and resulting damage to both the machine and the other object. Dual controls also allow operators to be trained with a minimum safety and time loss during actual paving operations.

c. Newer types of finishers are now in civilian use. These pavers feature improved power plants and either electronic or power assisted controls. Figure 32 depicts an improved type finisher.

46. Compaction Equipment

Discussion of compaction equipment is limited to bituminous operations. Unusual conditions or a shortage of a specified type of roller may necessitate the use of a nonrecommended type. The initial use of any compaction method should be on a trial and error basis. The use of compaction equipment as recommended herein will give the best results in a majority of circumstances.

Gal per Sq Yd	Nozzle size	Odometer reading	Pump tachometer readings [illegible]															
			8' Bar	9' Bar	10' Bar	11' Bar	12' Bar	13' Bar	14' Bar	15' Bar	16' Bar	17' Bar	18' Bar	19' Bar	20' Bar	21' Bar	22' Bar	24' Bar
.10	1/8	900	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
.10	3/16	1350	120	135	150	165	180	195	210	225	240	255	270	285	300			
.20	1/8	450	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
.20	3/16	675	120	135	150	165	180	195	210	225	240	255	270	285	300			
.25	1/8	360	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
.25	3/16	540	120	135	150	165	180	195	210	225	240	255	270	285	300			
.30	1/8	300	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
.30	3/16	450	120	135	150	165	180	195	210	225	240	255	270	285	300			
.40	1/8	225	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
.40	3/16	340	120	135	150	165	180	195	210	225	240	255	270	285	300			
.50	1/8	180	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
.50	3/16	270	120	135	150	165	180	195	210	225	240	255	270	285	300			
.60	1/8	150	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
.60	3/16	225	120	135	150	165	180	195	210	225	240	255	270	285	300			
.70	1/8	130	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
.70	3/16	195	120	135	150	165	180	195	210	225	240	255	270	285	300			
.75	1/8	120	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
.75	3/16	180	120	135	150	165	180	195	210	225	240	255	270	285	300			
.80	1/8	110	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
.80	3/16	170	120	135	150	165	180	195	210	225	240	255	270	285	300			
.90	1/8	100	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
.90	3/16	150	120	135	150	165	180	195	210	225	240	255	270	285	300			
1.00	1/8	90	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
1.00	3/16	135	120	135	150	165	180	195	210	225	240	255	270	285	300			
1.10	1/8	80	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
1.10	3/16	120	120	135	150	165	180	195	210	225	240	255	270	285	300			
1.20	1/8	75	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
1.20	3/16	110	120	135	150	165	180	195	210	225	240	255	270	285	300			
1.25	1/8	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
1.25	3/16	105	120	135	150	165	180	195	210	225	240	255	270	285	300			
1.50	1/8	60	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
1.50	3/16	90	120	135	150	165	180	195	210	225	240	255	270	285	300			
1.75	1/8	50	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
1.75	3/16	80	120	135	150	165	180	195	210	225	240	255	270	285	300			
2.00	1/8	[illegible]	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
2.00	3/16	70	120	135	150	165	180	195	210	225	240	255	270	285	300			
2.50	1/8	35	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
2.50	3/16	55	120	135	150	165	180	195	210	225	240	255	270	285	300			
3.00	1/8	30	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	240
3.00	3/16	45	120	135	150	165	180	195	210	225	240	255	270	285	300			

Figure 27. Tachometer chart.

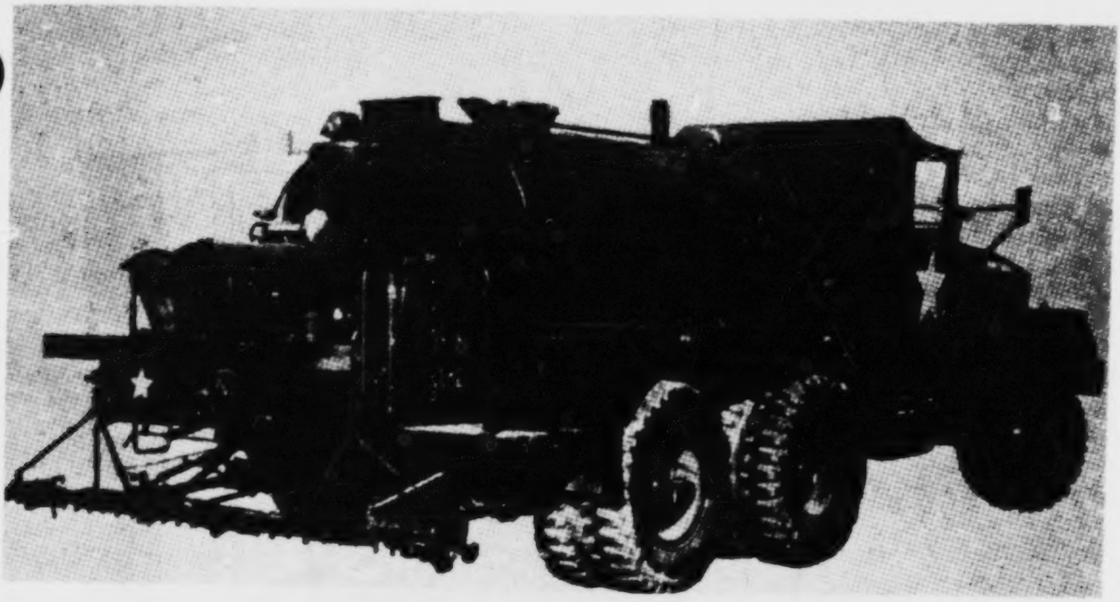

Figure 28. Truck-mounted asphalt distributor.

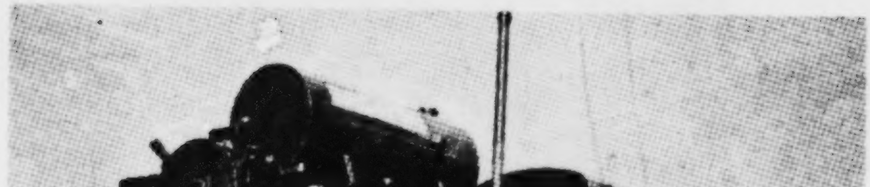

Figure 29. Tankless type, trailer-mounted asphalt distributor.

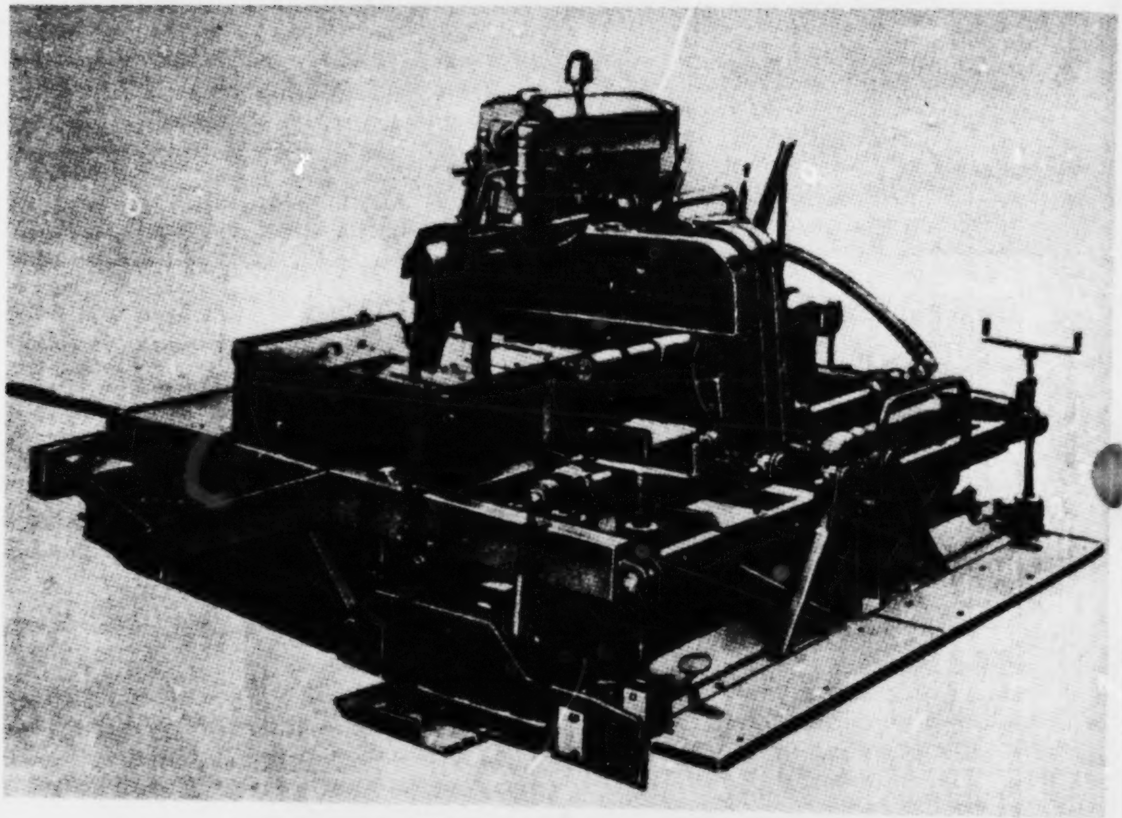

Figure 30. Model 879-B asphalt finisher.

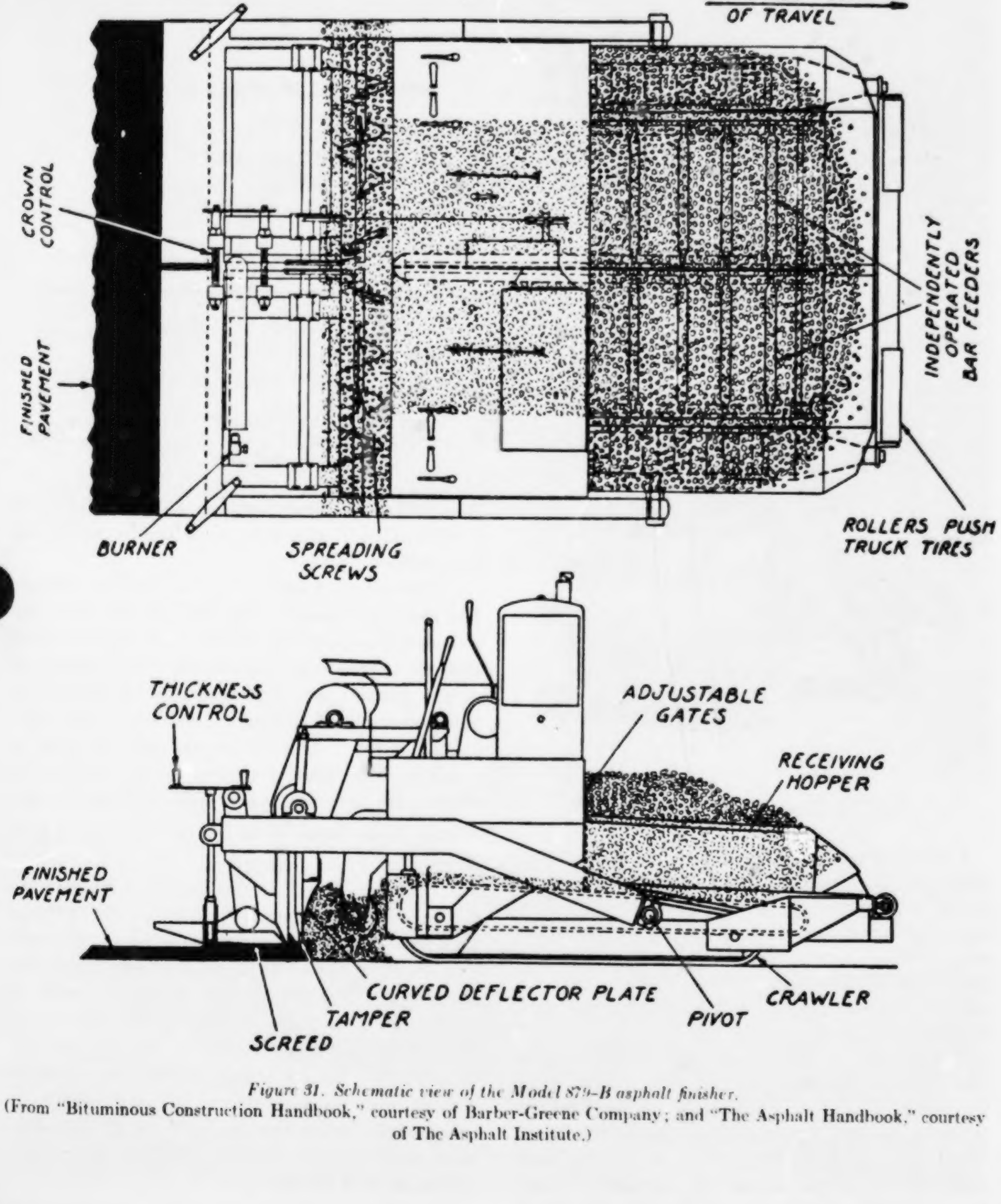
DIRECTION OF TRAVEL
CROWN CONTROL
FINISHED PAVEMENT
BURNER
SPREADING SCREWS
INDEPENDENTLY OPERATED BAR FEEDERS
ROLLERS PUSH TRUCK TIRES
THICKNESS CONTROL
ADJUSTABLE GATES
RECEIVING HOPPER
FINISHED PAVEMENT
CURVED DEFLECTOR PLATE
TAMPER
SCREED
PIVOT
CRAWLER

Figure 31. Schematic view of the Model 879-B asphalt finisher.
(From "Bituminous Construction Handbook," courtesy of Barber-Greene Company; and "The Asphalt Handbook," courtesy of The Asphalt Institute.)

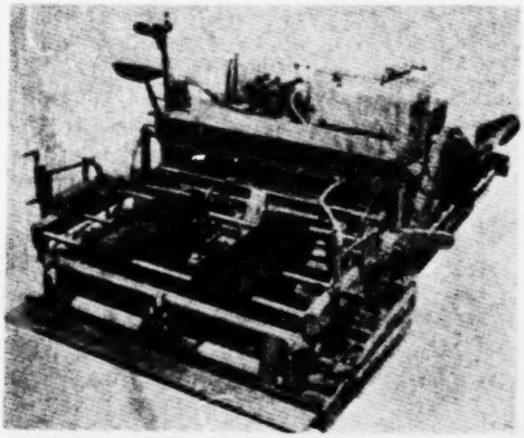

Figure 32. Improved type asphalt finisher.

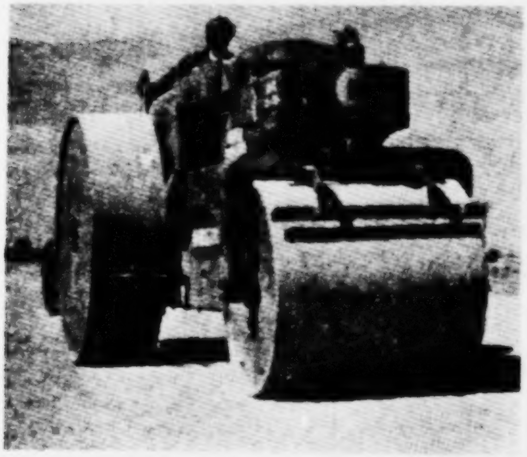

Figure 33. Three-wheel (10-ton) roller.

a. Three-Wheel (10-Ton) Roller. The three-wheel roller (fig. 33) is best suited for breakdown (initial) rolling of mixes placed by the asphalt finisher. The two large drive wheels should always precede the smaller driven wheel. Figure 34 demonstrates the importance of directional rolling. Additional information is given in TM 5–3895–207–10 and TM 5–3895–277–12P.

b. Two-Axle Tandem (5- to 8-Ton) Roller. The two-axle tandem (fig. 35) is a light general purpose roller. It is usually used for final rolling to remove surface irregularities caused by the three-wheel roller on large projects or it can be used alone for all of the compaction, including breakdown rolling on smaller jobs. Directional rolling precautions should be observed. Safety precautions must be rigidly observed when rolling on hills. TM 5–3895–211–12P should be consulted for additional information.

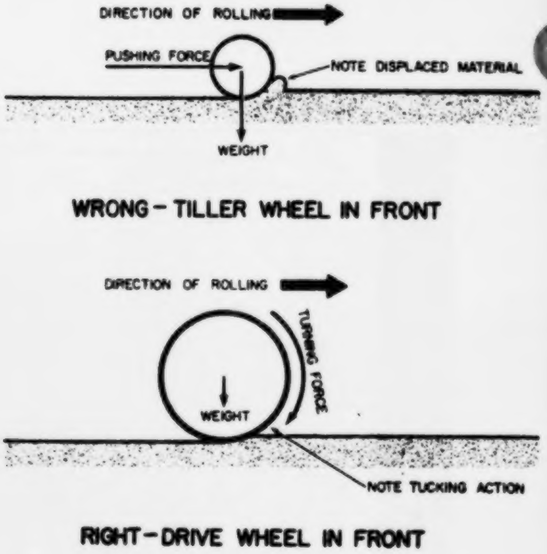

Figure 34. Importance of directional rolling.
(From "Asphalt Paving Manual," courtesy of The Asphalt Institute.)

c. Three-Axle Tandem (9- to 14-Ton) Roller. The three-axle tandem (fig. 36) has two vertically articulated tandem front wheels. This makes it most efficient in reducing high spots. The degree of weight transfer to a high spot may be selected by adjustment of the locking mechanism of the articulating section. This roller may also be used as a heavy duty, general purpose roller. Additional information is contained in TM 5–3895–214–12P.

Note. Future three-axle tandem rollers will be 13 to 18 tons.

d. Thirteen-Wheel, Pneumatic Tired Roller. The thirteen-wheel, pneumatic tired roller (fig. 37) has six wheels in the front and seven wheels in the rear. The wheels are offset from front to rear; thus, uniform compaction is obtained across the width of the roller. This roller should be used after compaction by steel wheel rollers to improve the surface texture. Rolling should be done in a random manner with no set pattern, but care should be exercised to insure that all sections of the pavement receive equal rolling. TM 5–1057 contains additional information.

Note. The thirteen-wheel, pneumatic tired roller will be replaced by a similar self propelled roller.

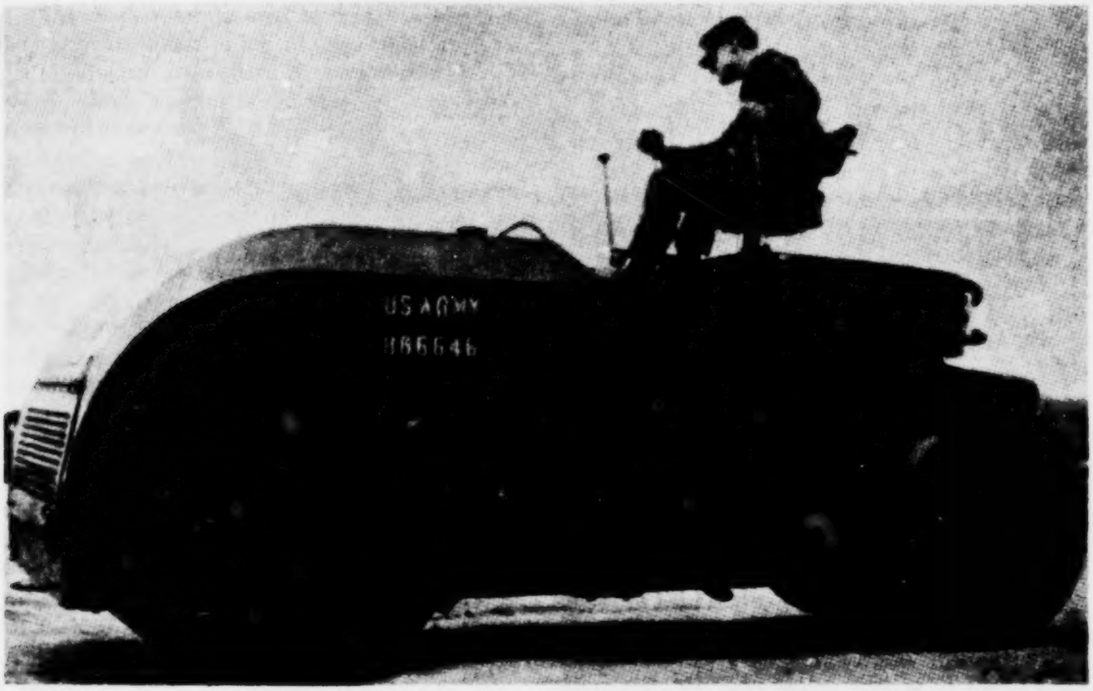
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Figure 35. Two-axle tandem (5- to 8-ton) roller.

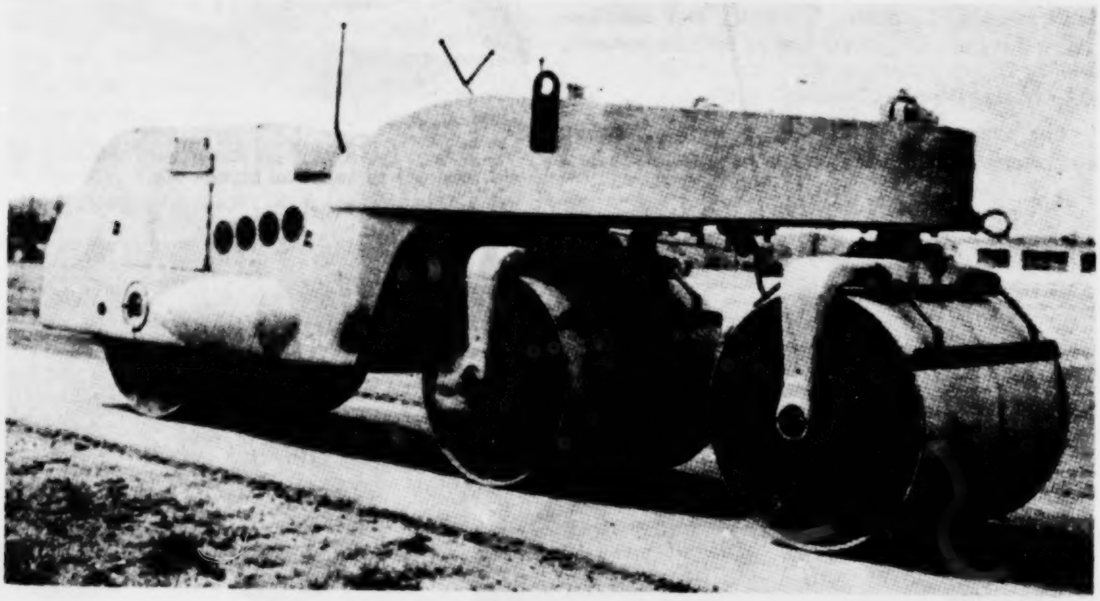


Figure 36. Three-axle tandem (9- to 14-ton) roller.

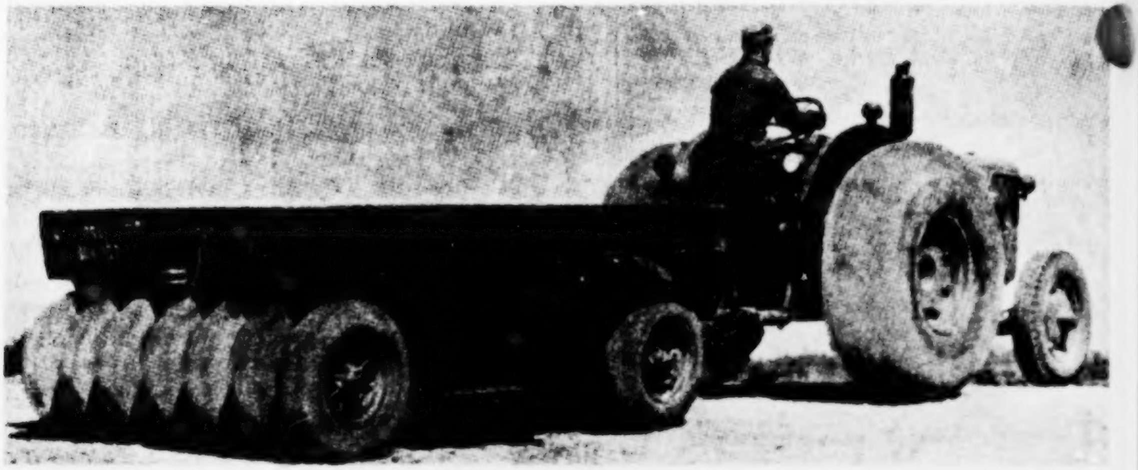


Figure 37. Thirteen-wheel, pneumatic tired roller.

e. Four-Wheel, Pneumatic Tired (50-Ton) Roller. The 50-ton roller (fig. 38) is used to proofroll airfield flexible pavements. A similar 200-ton model is used to proofroll airfields. The object of the proofrolling is to find points that will fail under traffic loading conditions, but provides an additional benefit of increasing compaction. For additional information see TM 5-1051.

f. Other Compaction Devices. Expedient hand tampers can be constructed to compact inaccessible areas and patches. Vibratory and combination rollers are in general use on civilian projects.

47. Motor (Patrol) Grader

The motor grader (fig. 39) has many uses in road and airfield construction work. Discussion here will be limited to bituminous construction. Further information can be found in TM 5-1092, TM 5-1027, TM 5-1018, TM 5-1039-1, TM 5-1033, TM 5-1041, and TM 5-1013.

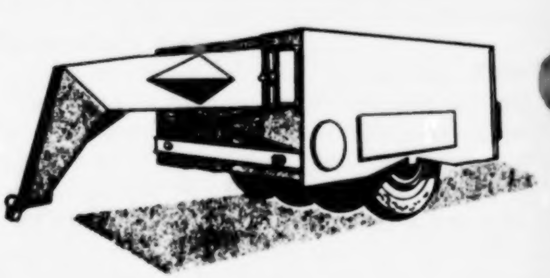


Figure 38. Four-wheel, pneumatic tired (50-ton) roller.

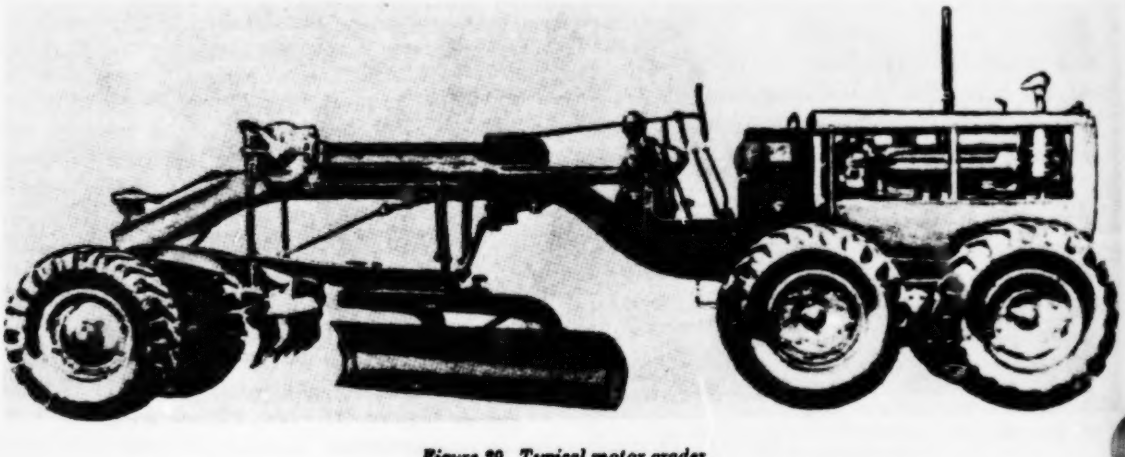


Figure 39. Typical motor grader.

a. The grader can be used to spread cold plant ixes and road mixes in lieu of the asphalt finisher. Good results can be realized if the operator is well trained. Grade control is difficult and some hand raking will be necessary.

b. Another use of the grader is to windrow, mix, and spread road mixes. The results are much poorer than those of a travel plant, but are acceptable for low class roads.

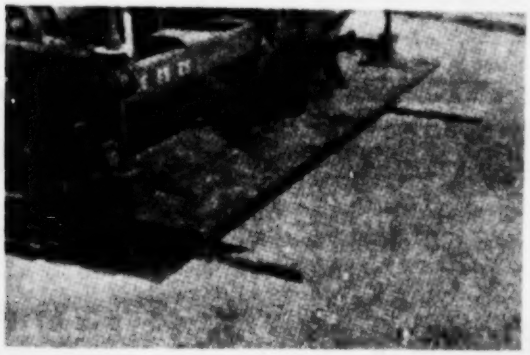
c. The grader is the best available equipment for manipulating and air drying road mixes.

48. Handtools

a. Rakes and Shovels. Rakes and shovels are used to spread bituminous mixes in small, inaccessible areas and in placing patches. They may be used to control the material flow into the paver hopper and to correct small surface irregularities. Before using, they should be heated and must be cleaned immediately after use.

b. Shims. Wooden shims hold up the floating screed at the beginning of paving operations. The finisher screed must be supported until it moves far enough forward to be supported by the mix itself. Figure 40 demonstrates the use of shims to upport the paver screed.

c. Straightedges. Straightedges are long rigid devices used for checking surface irregularities. Commercial varieties are metal and may be 10 to 16 feet long. Expedient models can be wood. Good results can be realized from two straight parallel 2 x 4's nailed or bolted to each other with a thin spacer in between. Although the expedient straightedge is bulky, smaller timber sizes tend to have too little rigidity. Care should be taken in the analysis of straightedge checks. Overlapping straightedge checks by at least 50 percent (fig. 41) will eliminate false straightedge readings. Figure 41 demonstrates a false straightedge reading.



igure 40. Use of shims to support the asphalt finisher floating screed.

d. Safety. It is common practice to clean handtools by burning off the bitumen. The men should exercise caution and be forewarned that the flames are not always visible. One man should stand by with a fire extinguisher capable of putting out a petroleum fire.

49. Aggregate Spreaders

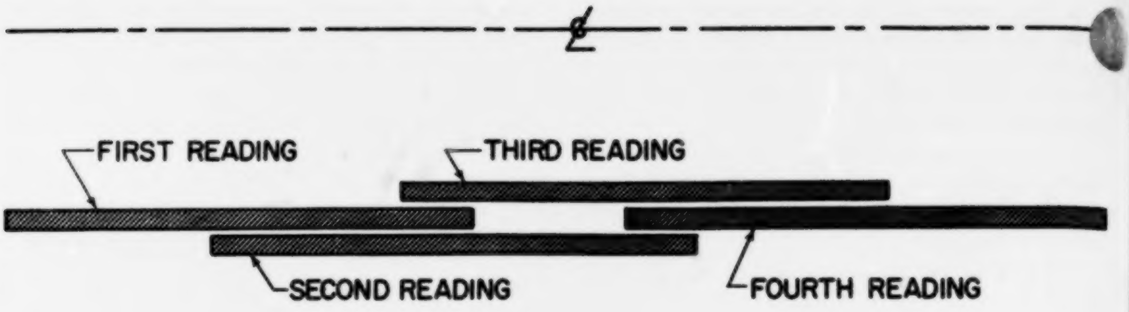
a. Standard Hopper-Type Spreader. The standard aggregate spreader (fig. 42) can handle aggregate which ranges from sand to 1½-inch gravel. The rate and depth of application depend upon the gate opening. The width of spread may be varied from 4 to 8 feet in 1-foot increments. Depending upon the manufacturer, the spreader has either two or four wheels. It hooks on the rear of a 5-ton dump truck and the truck backs up. This allows the aggregate to be spread on the bitumen ahead of the truck tires, thus preventing pickup of the bitumen. As a safety precaution, men should not be allowed to stand on the aggregate either in the truck or in the spreader at any time. Additional information is contained in TM 5–1000, TM 5–1083, and TM 5–3895–203–15.

b. Nonstandard Spreaders.

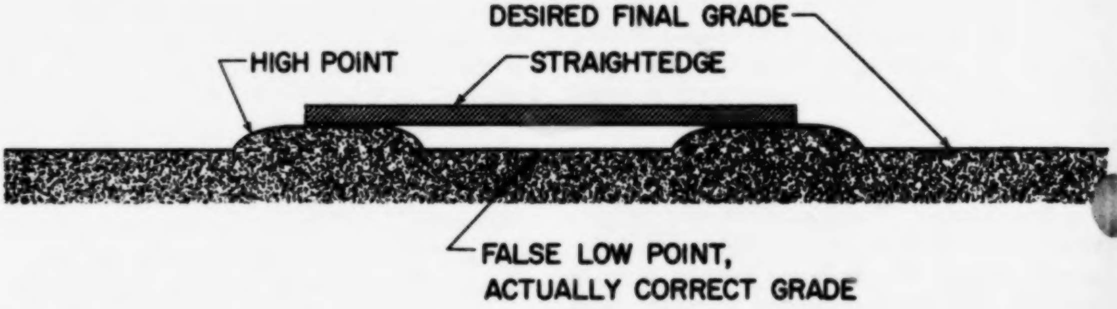
(1) The whirl type spreader is essentially a large disk that fits on the rear of a dump truck. The disk is parallel to the ground and slings the aggregate in a circle as it rotates.

(2) The vane spreader is a ribbed chute that fits on the rear of a dump truck. It acts as an extension of the dumpbed. Control is difficult and is not recommended for bituminous operations.

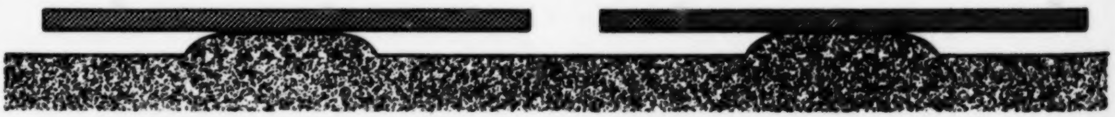
(3) The self-propelled spreader is constructed in a similar manner to the asphalt finisher. A hopper in the rear receives the aggregate from a dump truck. A conveyor transports the aggregate through the machine to the front where augers distribute the material across the face. The aggregate then goes through an adjustable screen which drops the larger aggregate first, then covers it with finer material. This machine provides the greatest degree of control and least segregation of any spreader.


℄
FIRST READING
THIRD READING
SECOND READING
FOURTH READING

METHOD OF OVERLAPPING


DESIRED FINAL GRADE
HIGH POINT
STRAIGHTEDGE
FALSE LOW POINT,
ACTUALLY CORRECT GRADE

FALSE READING (EXAGGERATED)



TRUE READING

Figure 41. Straightedge reading.

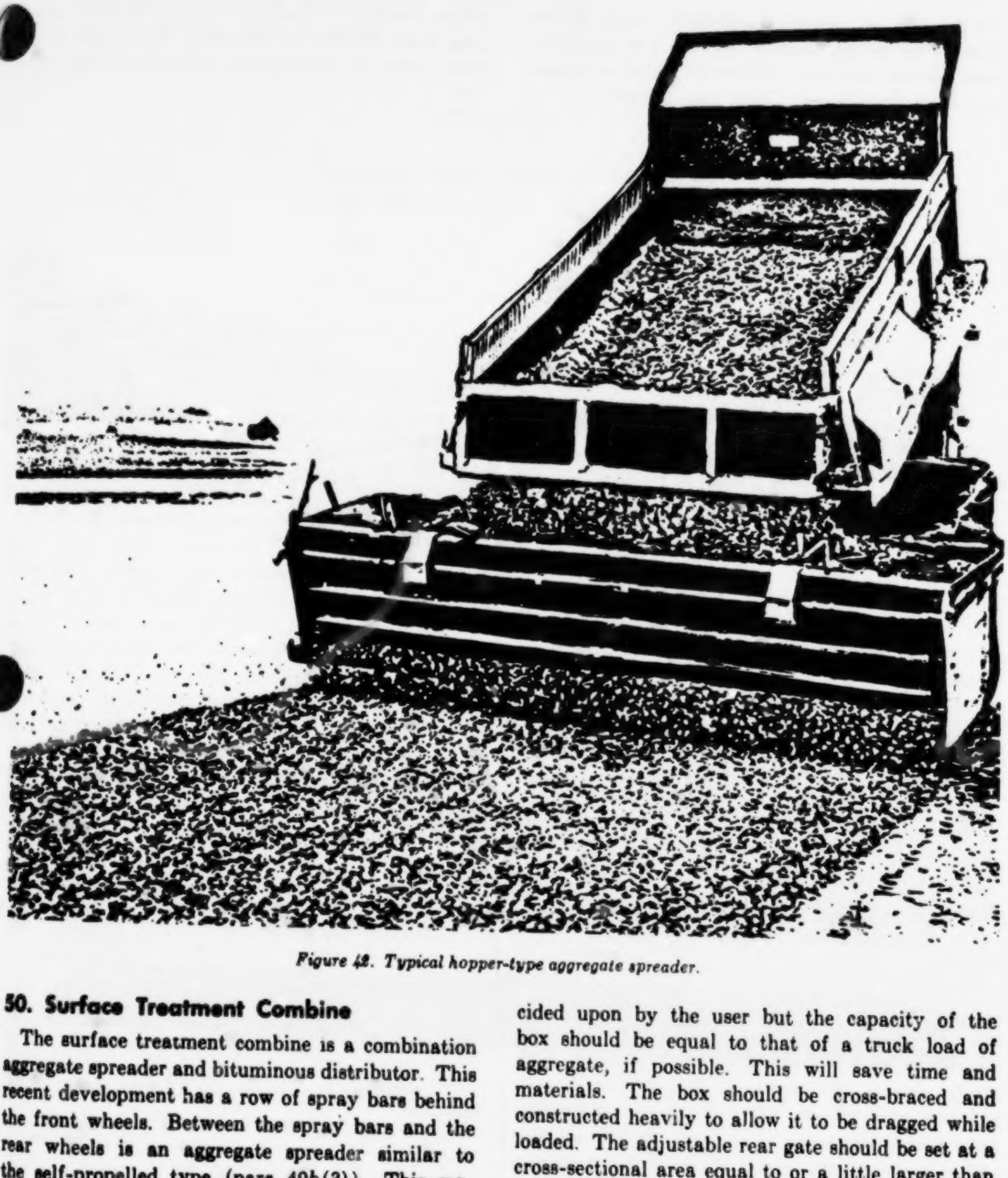


Figure 42. Typical hopper-type aggregate spreader.

50. Surface Treatment Combine

The surface treatment combine is a combination aggregate spreader and bituminous distributor. This recent development has a row of spray bars behind the front wheels. Between the spray bars and the rear wheels is an aggregate spreader similar to the self-propelled type (para 49*b*(3)). This machine is currently in limited civilian use.

51. Windrow Box

The windrow box is a piece of expedient equipment. Specific construction details must be decided upon by the user but the capacity of the box should be equal to that of a truck load of aggregate, if possible. This will save time and materials. The box should be cross-braced and constructed heavily to allow it to be dragged while loaded. The adjustable rear gate should be set at a cross-sectional area equal to or a little larger than the desired volume of aggregate per linear foot. Figure 43 shows a windrow box in use.

52. Drag Broom

The drag broom is usually available through normal supply channels, but may also be constructed in the field by expedient methods. Shop brooms and 3- by 6-inch timbers are the best expedient construction materials. Figure 44 shows a finished expedient drag broom. Note that a gap is left at the end of the oblique rows to prevent loose agg gate from drifting out the side. The useful life most brooms is extended by moistening them befor use.

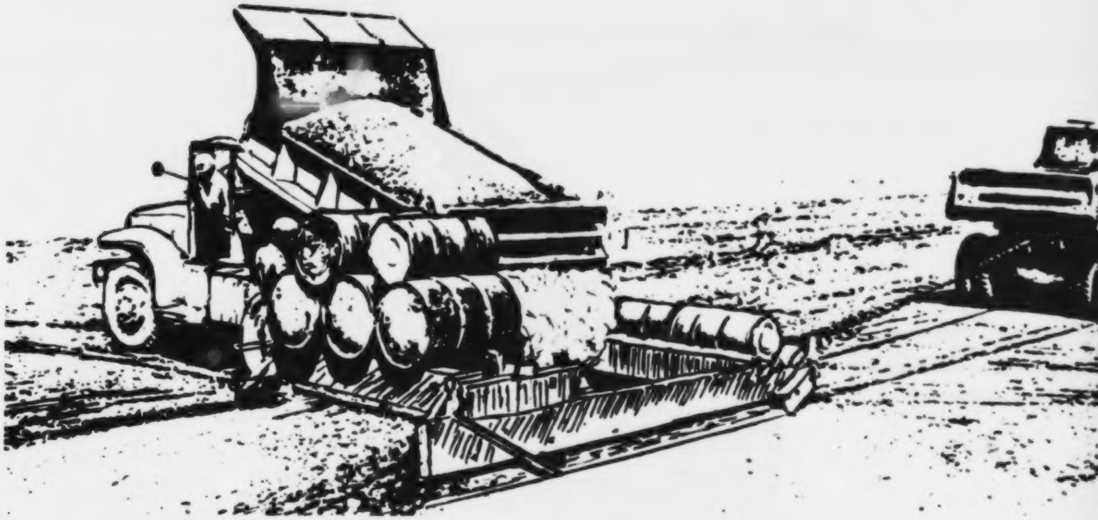


Figure 43. Windrowing aggregate with an expedient windrow box.

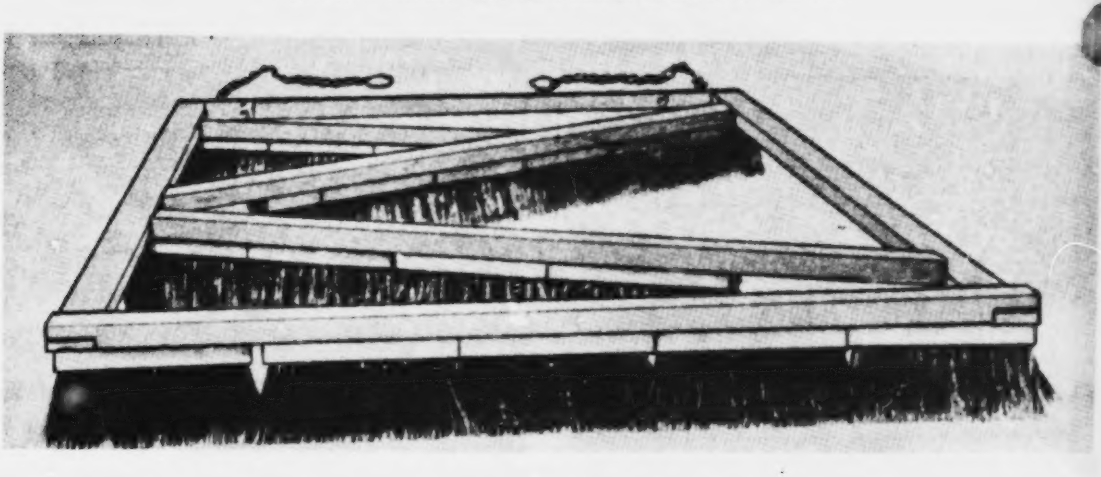


Figure 44. Drag broom.

CHAPTER 6

PRODUCTION AND LAYDOWN OF BITUMINOUS MATERIALS

Section I. INTRODUCTION

53. Bituminous Construction

A bituminous pavement (wearing surface) is a compacted mass of bituminous material and aggregate. Bituminous pavement may be constructed in one or more layers, with each layer usually 1 inch or greater in thickness. However, the laying of a thicker pavement in smaller lifts allows better compaction and therefore greater densities in the entire pavement mat. The layers distribute the load over the base through the interlocking action of the aggregate. Bituminous pavements are dependent on the base course for their load-carrying capacity. Bituminous pavements should be constructed over suitable base and subbase courses that will not be subject to excessive settling or deformation. The three types most widely used in the theater of operations are penetration macadam, road mix (mixed-in-place), and plant mix (hot-mixed, hot-laid plant mixes, and hot-and-cold-mixed, cold-laid plant mixes). This chapter discusses prime and tack coats, surface treatments, and production and laydown of bituminous pavements.

54. Storing and Dedruming Bituminous Material

Storing and dedruming bituminous material are discussed in the procedure for field manufacture of asphalt cutback in chapter 7.

55. Handling and Stockpiling Aggregate

Aggregate is transported in trucks from the pits where it is produced and screened to a location convenient to the construction. For processing the aggregate from pits and quarries, see TM 5–332. Aggregate is usually stockpiled both at the pit and at the construction site to prevent shortages while construction is in progress. Large stockpiles are usually rectangular for ease in computing volumes and built in layers or lifts with a flat top to retain uniformity of gradation and to avoid segregation. Separate stockpiles should be maintained for each aggregate when more than one aggregate or more then one size of aggregate are separately received. If aggregate is dumped into piles with long sloping sides, the aggregate may separate, with the larger particles falling down the slope, leaving the smaller particles near the top of the stockpile. The aggregate should be deposited in layers about 3 feet thick, either by maintaining a truck ramp at one end of the pile so the trucks can back up the ramp and dump over the top area of the stockpile to minimize segregation, or by building up the stockpile using a clamshell bucket without teeth. In the theater of operations, ramps may not always be used because of time limitations, and the aggregate may be deposited at ground level directly from the trucks.

56. Traffic Maintenance

a. Roads. Frequently, bituminous operations will be planned for roads that must carry traffic while work is in progress. Slow signs or other warning devices should be conspicuously placed at both 100 yards and 20 yards from each entrance to the project. Flagmen, dressed in safety vests or some other obvious attire, will aid in traffic control. A small vehicle acting as a pilot (lead) truck can greatly aid traffic control. The purpose of the pilot truck is to keep traffic off of freshly prepared surfaces and limit travel to a moderate speed when passing operations. Flagmen should organise the traffic in convoys for the pilot truck. A token, such as a red flag, is given the driver of the last vehicle in the convoy. He surrenders the token to the flagman on the far end as a sign that all traffic in the convoy has passed.

b. Airfields. It will be necessary for most airfields to remain operational during bituminous operations. A preconstruction conference should be held with the airfield safety officer. The construction schedule, equipment routing, and maximum height of equipment should be discussed. Liais with air traffic control must be established if truc and other equipment are to cross runways that in use.

Section II. PRIME COAT

57. Introduction

Before placing a bituminous wearing surface, it is necessary to apply a prime coat, consisting of a low viscosity liquid bitumen, to a properly prepared base. This prime coat should penetrate the base about ¼ inch, filling the voids. It acts as a waterproof barrier to prevent moisture that may penetrate the wearing surface from reaching the base. Also, the bitumen acts as a bonding agent, binding the particles of the base together and at the same time bonding the base to the wearing surface. Priming operations should be planned so that there will always be an adequate amount of cured primed base ahead of the surfacing operations, but not so far ahead that the base will become dirty or entirely dead. To preserve the base, it is desirable to apply a prime coat as soon as the base is ready; however, the prime coat will lose its effectiveness as a bonding agent if the wearing surface is not placed soon after curing.

58. Base Preparation

The base should be well graded, shaped to the desired cross section, compacted to specified density, well drained, free from excessive moisture but not completely dry, and swept clean. The surface of the base should be broomed if it contains an appreciable amount of loose material, either fine or coarse, or if it is excessively dusty. When brooming is omitted, a prime coat may be applied to the base and lightly rolled with a pneumatic roller, or light sprinkling with water may be used to settle the dust. Sprinkling is usually undesirable, but when it is necessary, a spray of water should be applied lightly at the rate of approximately 0.2 gallon to 0.3 gallon per square yard, depending on the condition of the base, the temperature, and the humidity. The base should be completely covered with a minimum amount of water and allowed to become dry or almost dry before the prime coat is applied, so that it will absorb the prime material. If the base is too wet, it will not take the prime properly and the moistrue will tend to come out, particularly in hot weather, and strip the prime from the base during construction. Rains also tend to strip the prime from a base that was too v when primed. Heavy rains may strip a proper primed base to some extent, but the tendency w not be so great as on an improperly cured ba In general, the lowest acceptable moisture conte for the upper portion of the base course prior priming should not exceed one-half of the optimu moisture content. On the other hand, if the ba dries out completely, cracks may develop and heavy rain may then cause swelling and loss density. See TM 5-335 for subgrade, subbase, a base course preparation.

59. Materials

Bituminous materials that may be used for pri coats are listed in table I. The material select will depend on the condition of the soil base a the climate. In moderate and warm climates, RT- RT-3, RT-4, MC-30, and MC-70 are satisfacto In cold climates, rapid-setting asphalt cutbac such as RC-70 and RC-250, have proved mo satisfactory. If the climate is very cold, the pri coat may be eliminated because it is likely to be e tremely slow in curing. RT-2 and MC-30 a satisfactory for a prime coat used on a dens graded base course. MC-70 is usually used loosely bonded, fine-grained soils, such as we graded sand. MC-250 is usually satisfactory coarse-grained sandy soils.

60. Application

The sequence of operations for the applicati of a prime coat is shown in figure 45. The pri coat is applied with a bituminous distributor (f 46). Temperatures for application of bitumen a given in table X. The rate of application per squa yard is adjusted in accordance with the porosi or density of the base, the prevailing atmospher temperatures, and the temperature and grade of t bitumen. The thinnest possible application shou be used that will effectively coat the base. T prime coat should extend at least 1 foot beyond t edge of the surface that is to be placed on ea side to waterproof the base and assure comple coverage. If the base course has a low PI, exte the prime coat far enough to include the base ourse shoulders. In general, the rate of application should vary between 0.2 gallon and 0.5 gallon per square yard. Soils with many voids require a higher rate of application than dense soils. *For example,* a uniform open-graded sand may require 0.4 gallon per square yard to fill the voids, whereas a tightly bonded, fine-grained soil may require approximately 0.2 gallon per square yard. To establish the rate of application, trial runs should be made on a test strip. If the quantity obtained does not equal the desired quantity per square yard, an adjustment in the rate of application will be necessary. The speed of distributor and the necessary rate of discharge for a specified rate of application in gallons per square yard may be obtained by using a tachometer chart (fig. 27) that usually comes with the distributor. Because of variable conditions, continuous adjustment of the distributor is usually necessary while the prime coat is being applied. (Safety precautions for use of bituminous materials should be observed.)

61. Underpriming

If the base absorbs all of the prime material within 1 to 3 hours or if penetration is too shallow, the base is underprimed. Under priming may be corrected by applying a second coating of the prime material after the first application.

62. Overpriming

Overpriming is more undesirable than underpriming. An overprimed base may fail to cure and contribute to failure of the pavement. A free film of prime material remaining on the base after a 48-

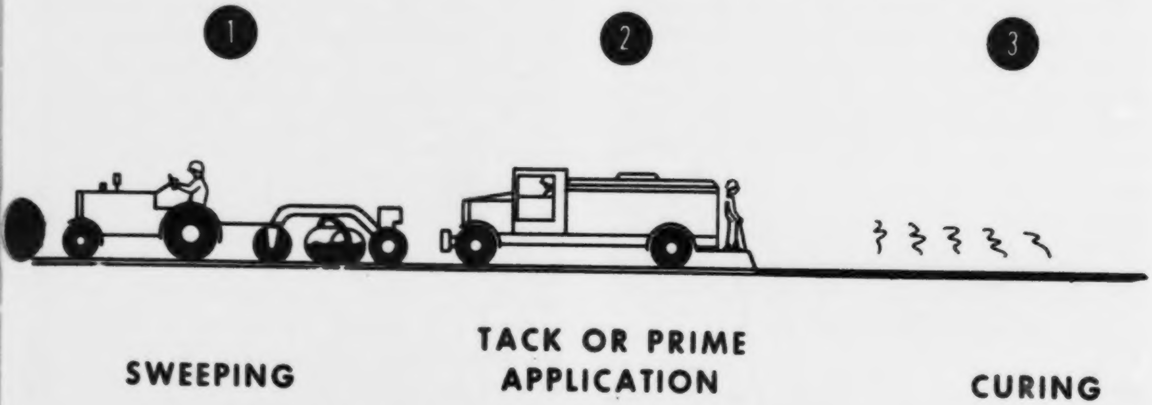


Figure 45. Sequence of operations for the application of prime and tack coats.
(From "Bituminous Construction Handbook," courtesy of Barber-Greene Company.)

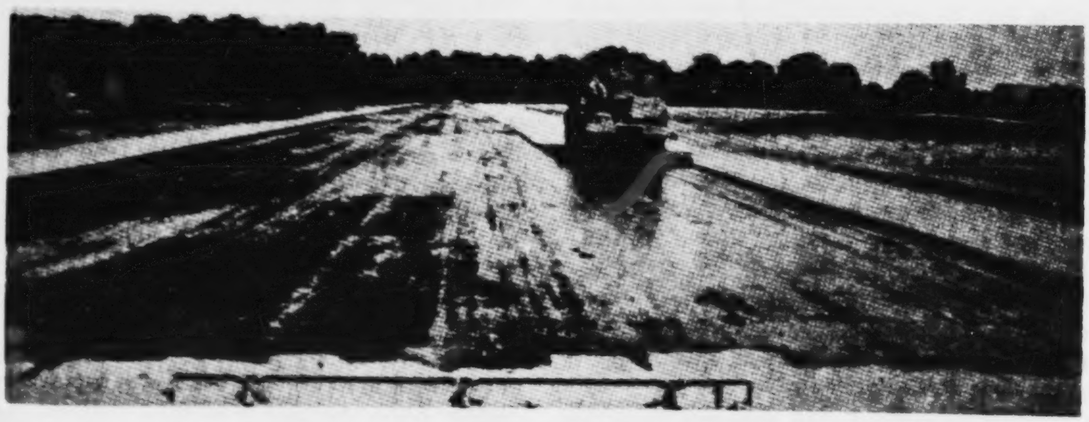


Figure 46. Applying a prime coat to an airfield runway with a bituminous distributor.

hour curing period indicates that the base is overprimed. This condition may be corrected by spreading a light, uniform layer of clean, dry sand over the prime coat to absorb the excess material. Application of the sand is usually followed by light rolling and brooming. Excess prime held in minor depressions should be corrected by an application of clean, dry sand. Any loose sand should be lightly broomed from the surface before the wearing surface is laid.

63. Curing

The primed base should be adequately cured before the surface course is laid. In general, a minimum of 48 hours should be allowed for comple curing. Ordinarily, proper surface condition is i dicated by a slight change in the shiny black a pearance to a slightly brown color.

64. Protection

The soil base that is to be covered by a bitumino wearing surface should be barricaded to preve traffic from carrying dust or mud onto the surfa both before and after priming. If it is necessary open the primed base course to traffic before it h completely cured, a light sand may be used described in paragraph 62 to absorb the exce material.

Section III. TACK COAT

65. Introduction

A tack coat is a sprayed application of a bituminous material that is applied to an existing wearing surface of concrete, brick, bituminous material, or binder course before a new bituminous pavement is placed over the existing surface. The purpose of the tack coat is to provide a bond between the existing pavement and the new surface. The tack coat should become tacky within a few hours. A tack coat is not required on a primed base unless the prime coat has completely cured and become coated with dust. Figure 45 shows the sequence of operations for the application of a tack coat.

66. Materials

Bituminous materials usually used for tack coats are given in table I. Rapid-curing cutbacks, road tar cutbacks, rapid-setting emulsions, and medium asphalt cements are generally suitable for a tack coat. RC grades 250 or 800 are most satisfactory because they become tacky rapidly. Because rapid-curing cutbacks are highly flammable, safety precautions prescribed for handling bituminous materials must be followed. Emulsions can be used in warm weather. If facilities are available, 200 to 300 penetration grade asphalt cement may be used with excellent results.

67. Application

a. Surface Preparation. The existing surface must be swept clean to permit the tack coat to adhere to it.

b. Method and Rate. The tack coat is applied with a bituminous distributor as described in paragraph 60 for a prime coat at the temperatures pr scribed for spraying. Unlike the prime coat, t tack coat is generally applied only over the wid of the existing surface that is to be surfaced. tachometer chart (fig. 27) may be used to esta lish rate of application. The usual rate of applic tion varies between 0.05 and 0.25 gallon p square yard. On a smooth, dense, existing surfa the minimum rate of 0.05 gallon per square ya should produce a satisfactory bond. If the surfa is worn, rough, and cracked, the maximum rate 0.25 will probably be required. An extremely hea tack coat may be absorbed into the surface mixtu resulting in a bleeding and flushing action and lo of stability. The surface should be rolled light with a rubber-tired roller or truck tires for unifor distribution of the bituminous material.

68. Curing

The tack coat should be completely cured befo the surface course is laid. A few hours should sufficient for curing. A properly cured surface w feel tacky to the touch; further curing is requir if the cutback or emulsion comes off easily und light finger pressure. If the wearing surface is la before the tack coat has become tacky, the volat substances may act as a lubricant and prevent bon ing with the wearing surface. If the tack coat har ens, the heat from a hot bituminous mix or t cutterstock in asphalt cutback will usually soft it enough for a bond to develop between the o and the new surface. A tack coat that becom coated with dust will not bond with the weari surface unless the dust is broomed from the su face.

69. Protection

The existing surface that is to be covered by a bituminous wearing surface should be barricaded to prevent traffic from carrying dust or mud onto the surface either before or after the tack coat is applied. Should it become necessary for traffic to use the surface, one lane may be tack coated and paved, using the other lane as a traffic bypass. The bypass lane should be primed and sanded before opening to traffic. It should be swept and reprimed after the adjacent lane is completed. This preserves the base and acts as a dust palliative.

Section IV. SURFACE TREATMENT

70. Introduction

A single surface treatment usually consists of a sprayed application of a bitumen and aggregate cover one stone thick. Surface treatment may be referred to as a seal coat, armor coat, or carpet coat. A single surface treatment is usually less than 1 inch thick. Surface treatments serve only as an abrasive and weather-resisting medium which waterproofs the base. Generally, they are not as durable as bituminous concrete and may require constant maintenance. Surface treatments are particularly suitable for surfacing aged or worn bituminous pavements that are dry, raveled, or beginning to hair crack. Well-designed and well-constructed new bituminous pavement should possess a surface texture that does not require surface treatment to fill the voids. Surface treatments are used largely on roads. Although not recommended for airfields, they may be used as an expedient measure. They are particularly suitable for theater-of-operations construction because they may be laid quickly with a minimum of materials and equipment, they may be constructed in multiple layers with little interference to traffic, and they may be used as the first step in stage construction. Surface treatment will not withstand the action of metal wheels on vehicles, tracked vehicles, or nonskid chains on vehicle wheels. Surface treatments should not be attempted except when the temperature is above 50° F. The three requirements for a surface treatment are as follows:

a. The quantity of the bitumen must be sufficient to hold the stone without submerging it.

b. Sufficient aggregate must be used to cover the bitumen.

c. The base course on which the surface treatment is laid must be sufficiently strong to support the anticipated traffic load.

71. Single Surface Treatment

A single surface treatment consists of an application of bitumen covered with mineral aggregate, rolled to a smooth even-textured surface. Figure 47 shows the sequence of operations for the application of a single surface treatment.

72. Aggregate

Uniformly graded sand or crushed stone, gravel, or slag may be used for surface treatments. The purpose of the surface treatment determines the size of aggregate to be selected. For example, coarse sand may be used for sealing a smooth existing surface. For a badly broken surface, the maximum size of the aggregate should be about ½ inch; the minimum size should pass the No. 4 sieve. Gradation specification limits for surface treatments are given in table II.

73. Bitumen

As shown in table I, RC cutbacks, MC cutbacks, road tars, rapid-setting emulsions, and asphalt cements may be used for surface treatment. RC cutbacks are most widely used because they evaporate rapidly and the road can be opened to traffic almost immediately after application of the surface treatment. Viscosity grades of the bitumen depend on the size of the aggregate used as coverstone. The larger particles of aggregate require a bitumen of higher viscosity so that the bitumen will hold the aggregate. For example, RC–70 or RC–250 may be used with coarse sand for a surface treatment to seal cracks in an otherwise satisfactory surface. For resurfacing a badly cracked or rough surface, RC–800 or RC–3000 may be used with ¾-inch aggregate.

74. Application of Bitumen

Surface treatments are usually applied to a thoroughly compacted primed base that has been swept clean. The existing surface or base course must be dry or contain moisture not in excess of that which will permit satisfactory bonding of surface treatment to the base. Atmospheric temperature should be above 50° F. To assure uniform distribution, the bitumen should be applied with a bitu-

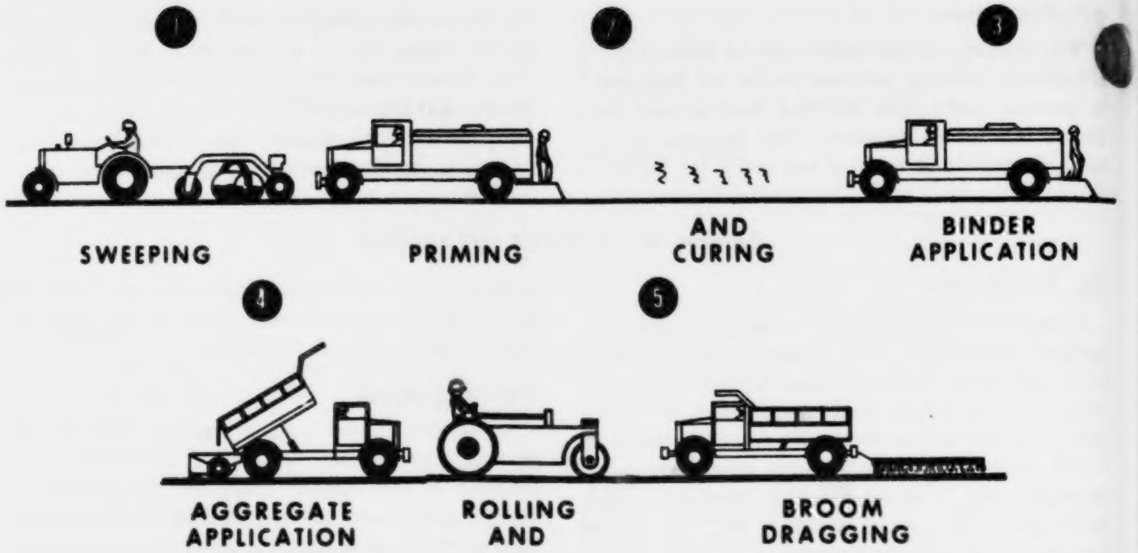


Figure 47. Sequence of operations for the application of a ~~single surface~~ treatment. (From "Bituminous Construction Handbook," courtesy of Barber-Greene Company.)

minous distributor. The quantity of the bitumen required is based on the average particle size of the coverstone. Table VI gives the bitumen required for single surface treatments. The bitumen must be sufficient to hold the aggregate in place without leaving a sticky surface. The aggregate must not be completely submerged in the bitumen. The viscosity used is dependent upon the size of the coverstone; the larger the coverstone, the higher (or thicker) the viscosity of the bitumen. One-quarter-inch aggregate should be submerged approximately 30 percent; 3/8-inch aggregate, 32 percent; 1/2-inch aggregate, 35 percent; and 3/4-inch aggregate, 43 percent. Approximately 1 gallon of bitumen is usually used for 100 pounds of aggregate.

Example: What is the recommended rate of bitumen application, in gallons per square yard, if 30 pounds of aggregate are required to cover an area of 1.0 square yard?

Solution:

$$R = (30 \text{ lb/sq yd}) \times \left(\frac{1.0 \text{ gal}}{100 \text{ lb}}\right) = 0.30 \text{ gal/sq yd}$$

75. Application of Aggregate

The aggregate is spread immediately after application of the bitumen while the bitumen is still fluid. An adjustable mechanical aggregate spreade may be used as shown in figure 48, or the aggregat may be spread from trucks or by hand. Trucks should be operated backward so that the truck wheels will move over the bitumen that has been covered with aggregate. For handspreading, aggregate should be dumped in piles adjacent to the areas to be treated, and spread by hand. If the aggregate is spread unevenly, the surface should be drag broomed to provide complete uniform coverage of the bitumen and to obtain a smooth, even surface.

76. Rolling

While drag brooming (fig. 49) is being performed the surface is rolled with a 5- to 8-ton roller. A heavier roller is likely to crush the aggregate rather than embed the particles in the bitumen. Crushing is to be avoided because crushed particles change

Table VI. Quantities of Aggregate and Bitumen for Single Surface Treatments

Material	Unit of measurement	Gradation designations						
		No. 24–A	No. 24–B	No. 25–A	No. 25–B	No. 26–A	No. 27–B	No. 27–C
Aggregate	Lb per sq yd	35–45	35–45	25–35	25–35	15–25	10–15	10–20
Bitumen	Gal per sq yd	0.35–0.45	0.35–0.45	0.25–0.35	0.25–0.35	0.15–0.25	0.10–0.15	0.10–0.20

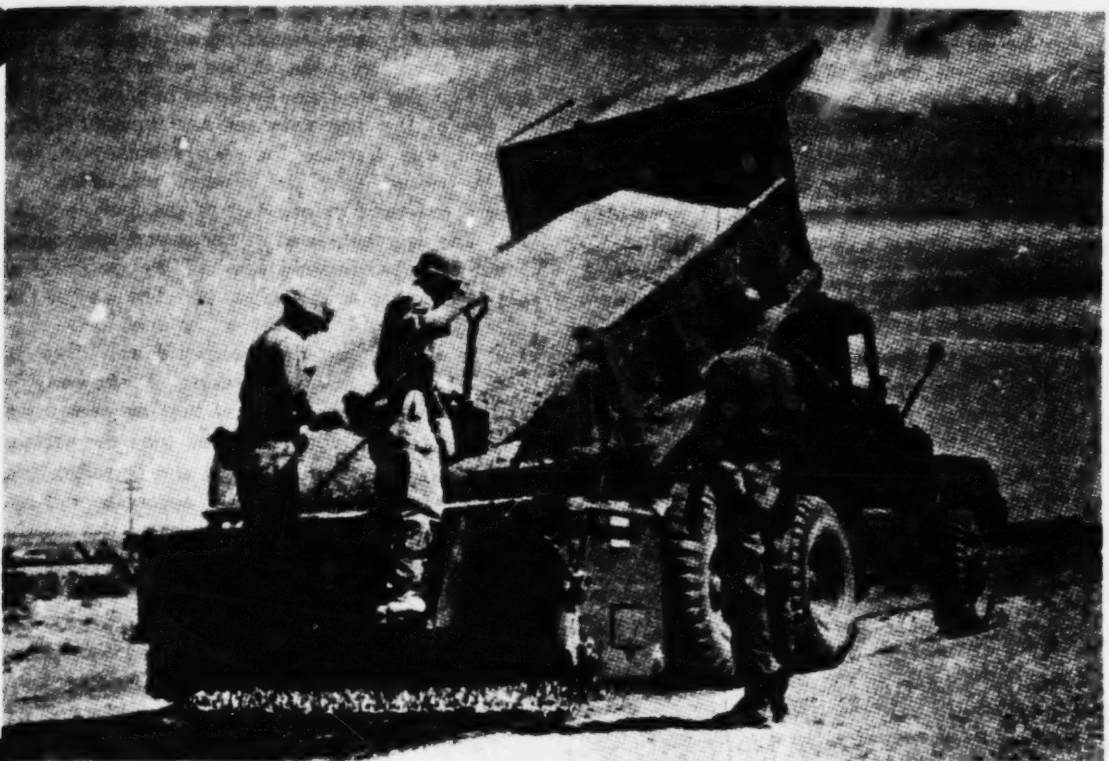


Figure 48. Hopper-type spreader applying aggregate to a surface treatment.

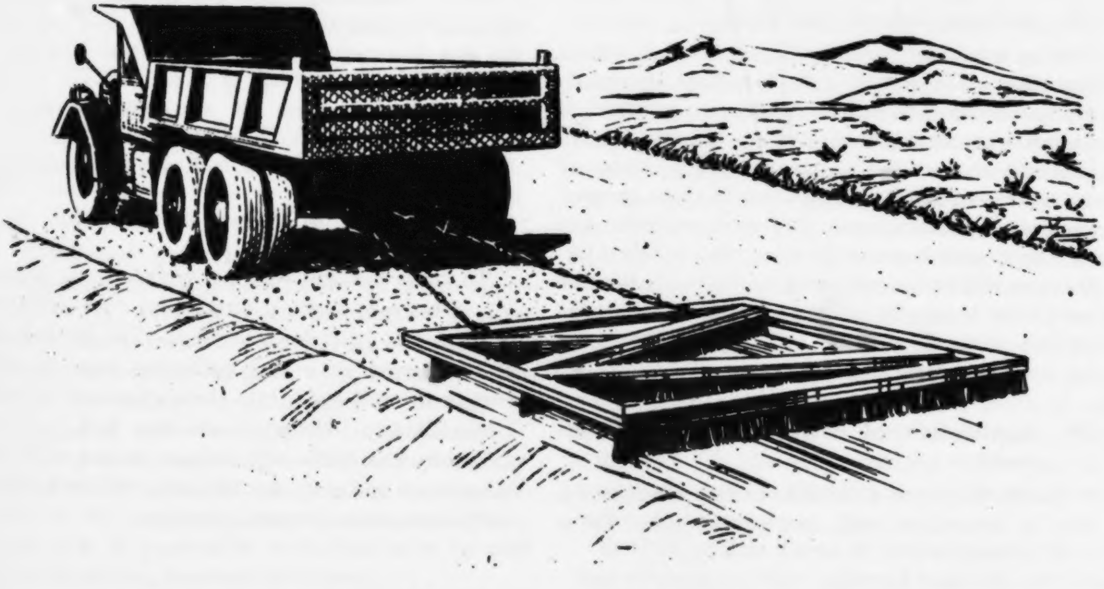


Figure 49. Drag brooming a surface treatment.

the selected gradation of the aggregate. Rolling should be done in accordance with instructions given below.

a. Rolling should be parallel to the centerline of the roadway to reduce the number of times the roller must change direction.

b. To assure complete coverage, succeeding passes should overlap one-half of the wheel width of the roller.

c. To assure that the aggregate is well embedded in the bitumen, rolling should be completed before the bitumen hardens.

d. To maintain surface crown and to prevent feathering at the edges, succeeding passes should be made from the low side to the high side of the surface.

e. Rolling should be done at a slow speed.

f. Rolls should be wet to prevent bitumen from sticking to wheels.

g. The power roll should pass over the unrolled surface before the steering roll.

77. Final Sweeping

After rolling and curing, the surface treatment is ready for traffic. If the surface treatment is used on an airfield, excess aggregate must be swept from the surface to avoid damage to aircraft. This practice is also recommended for roads, although it is not essential.

78. Multiple Surface Treatment

When a tougher, more resistant surface is desired than that obtained with a single surface treatment, multiple surface treatment may be used. Multiple surface treatment is two or more successive layers of single surface treatment. Smaller particles of aggregate and correspondingly less bitumen are used for each successive layer. Although multiple surface treatments are usually more than 1 inch thick, they are still considered surface treatments because each layer is usually less than 1 inch and the total surface treatment does not add appreciably to the load-carrying capacity of the base.

79. Application of Multiple Surface Treatment

The first layer of a multiple surface treatment is laid in accordance with instructions given for a single surface treatment in paragraphs 71 through 77. Loose aggregate remaining on the first layer must be swept from the surface so that the layers may be bonded together. As stated in paragraph 78, the size of the aggregate and the amount of the bitumen will decrease for each successive layer. For the second layer, the bitumen will usually be reduced one-third or one-half of the first application. The aggregate used in the second application should be approximately one-half the diameter of that used in the first application. The size of the aggregate and the amount of bitumen ordinarily used in double surface treatments are given in table VII. The final application of aggregate is drag broomed, if necessary, so that an even layer of aggregate will remain. At the time the surface is being drag broomed, it should also be rolled with a 5- to 8-ton roller so that the aggregate will become embedded in the bitumen. After the surface is rolled and cured, it is ready for traffic. If the multiple surface treatment has been laid on an airfield, loose aggregate must be swept from the surface so that it will not damage the aircraft. Final sweeping is also recommended for roads.

Table VII. Quantities of Aggregate and Bitumen for Multiple Surface Treatments

Gradation designations	Bitumen (gal per sq yd), first application	Aggregate (lb per sq yd), first spreading	Bitumen (gal per sq yd), second application	Aggregate (lb per sq yd), second spreading
No. 23–A	0.45–0.55	45–55		
No. 25–A			0.2–0.3	15–25
No. 24–A	0.40–0.50	40–50		
No. 26–A			0.2–0.3	15–25
No. 25–A	0.35–0.45	35–45		
No. 27–A			0.2–0.3	15–25

80. Dust Palliative

To prevent a soil wearing surface from becoming excessively dusty, a bituminous dust palliative is applied to hold down the dust. The bituminous material used as a dust palliative must be thin enough to soak easily into the surface and it must retain fluidity indefinitely so that dust particles raised by the traffic will become coated with the bituminous material. An MC–70 or SC–70 cutback is the best material for this purpose.

Section V. PENETRATION MACADAM

81. Introduction

Penetration macadam pavements consist of crushed stone or crushed slag, bonded with bituminous materials by the penetration method, constructed on a previously prepared base or subbase course. They are used as a wearing surface for roads or as a binder or base course in stage construction of both roads and airfields. They also may be used as a surface course on overrun areas of airfields not subject to blast. Penetration macadam pavements are particularly suitable for use in remote localities or for small paving areas. Construction is rapid and a minimum of equipment is required. Because the method of construction cannot be accurately controlled, the finished surface is less dense than the surface of plant-mix pavement, and loose aggregate may be a hazard to traffic, particularly on airfields.

82. Materials

a. Bituminous Materials. Bituminous materials that may be used for penetration macadam wearing surfaces are given in table I. Emulsions are sometimes used for penetration macadam base courses.

b. Aggregate. Three sizes of aggregates are used in the construction of a penetration macadam: Macadam aggregate (coarse); uniformly graded keystone (intermediate aggregate); and uniformly graded fine aggregate, or chokestone (stone chips or clean, coarse sand). Coarse aggregate and keystone should consist of clean, tough, durable particles or fragments of stone or crushed slag. Recommended gradations for penetration macadam wearing surfaces are given in table II.

83. Construction Procedure

Penetration macadam surface courses must be constructed on a dry base course when the aggregate is dry, the atmospheric temperature is about 60° F., and the weather is not foggy or rainy. The method of constructing penetration macadam pavements is discussed in paragraphs 84 through 98. Sequence of operations (fig. 50) is as follows:

a. Inspect the base, and recondition as necessary.

b. Prime the base if waterproofing or consolidation of the top of the base is necessary. (Use a tack coat if penetration macadam is to be used over an existing pavement as a base.)

c. Spread macadam aggregate.

d. Roll.

e. Apply first application of bitumen.

f. Apply keystone.

g. Drag broom and roll.

h. Apply second application of bitumen.

i. Apply chokestone.

j. Drag broom, roll, and hand broom the surface.

k. Apply surface treatment when additional waterproofing is necessary.

84. Reconditioning the Base Course

Inspect the base for criteria given in paragraph 58. Discrepancies of defective areas in the base that may exist or develop during construction must be corrected. Penetration macadam pavements must be built over well-compacted, adequate bases. All dust and debris must be swept from the surface of the base so that the prime coat will be absorbed by the base. A tack coat may be used when penetration macadam is constructed on an existing pavement, although it may not be necessary.

85. Edges of Wearing Surface

If time is of greater importance than materials conservation and appearance, the procedures outlined herein may be omitted. However, some type of shoulders should be placed as soon as possible.

a. With Side Forms. Where no permanent edgings, curbs, or gutters are present, side forms, securely staked and backed with earth or other material, may be installed in advance of the spreading of coarse aggregate. Side forms may be either wood or metal, constructed so that they can be securely and rigidly fastened in place to the lines and grades specified. The forms should be sufficient in number and length to properly accommodate the control construction. Ten-foot to twelve-foot lengths should be used except on curves having a radius of 150 feet or less, where sections of 5 feet are acceptable. The depth of the forms should be ¼ inch less than the depth of the finished pavement. Side forms should be backed with earth or other suitable materials on the berm side to a width of not less than 2 feet, and to such height that, when thoroughly compacted, the backing will be approximately the same as the thickness of the compacted wearing course.

b. Without Side Forms. If well-compacted shoulders of earth or other approved material are to be constructed before the coarse aggregate is spread,

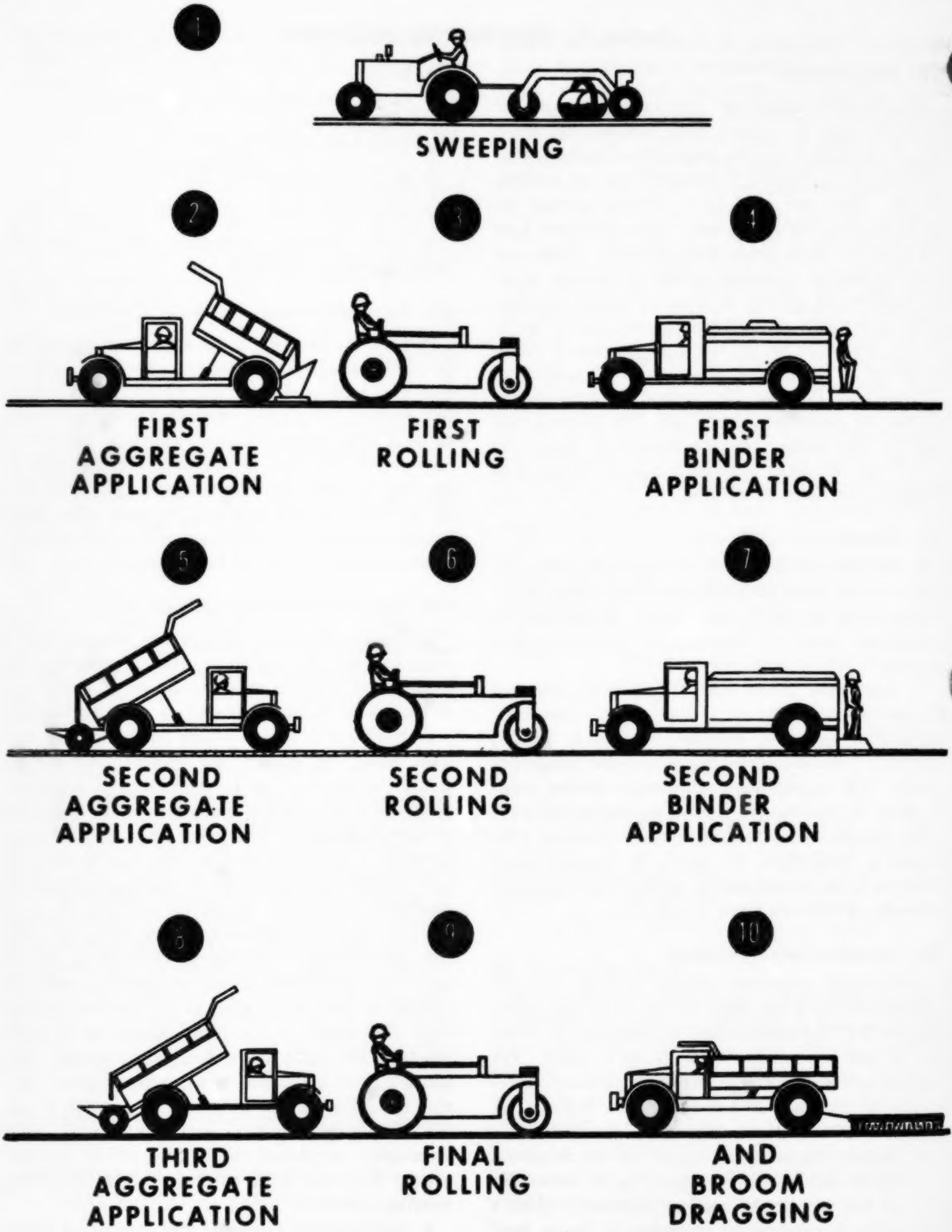

1
SWEEPING
2
FIRST AGGREGATE APPLICATION
3
FIRST ROLLING
4
FIRST BINDER APPLICATION
5
SECOND AGGREGATE APPLICATION
6
SECOND ROLLING
7
SECOND BINDER APPLICATION
8
THIRD AGGREGATE APPLICATION
9
FINAL ROLLING
10
AND BROOM DRAGGING

Figure 50. Sequence of operations for the application of penetration macadam.
(From "Bituminous Construction Handbook," courtesy of Barber-Greene Company.)

the shoulders should be approximately 2 feet wide, and have vertical faces equivalent to the depth of the wearing course. They should be constructed of material which is free from sod, weeds, or other unsuitable matter, and to full width and height to hold the wearing course material in place while it is being spread and rolled.

86. Application of Macadam Aggregate

The road or runway is divided into strips of convenient width. The loose, coarse aggregate is uniformly spread with improvised or standard stone spreaders, by hand, or with a modified bituminous finisher at a loose depth that will give the required compacted thickness. A test section should be used to establish the required depth, which may be in the ratio of about 3½ inches of loose aggregate for a 2½-inch compacted thickness. Any thin, flat, oversized aggregate that appears on the surface at any time during construction should be removed; also all areas of fine material should be removed and replaced with macadam aggregate before rolling. Maximum aggregate size should usually be two-thirds the thickness of the compacted layer. If the aggregate is larger, the oversized particles may prevent proper compaction or they may be crushed by the compacting equipment.

87. Rolling

The uniformly spread macadam aggregate should be compacted and mechanically bonded by dry-rolling with a 10-ton, three-wheel roller. Rolling should progress gradually from the sides to the center, except that on superelevated curves, rolling may progress from the lower to the upper edge parallel with the centerline of the lane, overlapping uniformly each preceding rear wheel track by one-half the width of such track, and continuing until the aggregate does not creep or wave ahead of the roller. At the sides, where no permanent edgings are present, the outside wheel of the roller should cover equal portions of the spread aggregate and the shoulder. The roller should run forward and backward until the shoulder is firmly compacted against the edge of the pavement. Along curbs, headers, and walls, and at all places not accessible to the roller, the aggregate should be tamped thoroughly with mechanical or hand tampers. Material, which crushes under the roller in such manner as to prevent free and uniform penetration of the bituminous material, or any aggregate in this or any subsequent spreading that becomes coated or mixed with dirt or clay prior to the application of the bituminous material, should be removed, replaced with clean aggregate, and rerolled. Any irregularities greater than ⅜ inch from specified lines and grades, as determined by testing of the surface with a 10-foot straightedge laid parallel to the centerline of the pavement, should be corrected by loosening and reshaping the aggregate, removing or adding aggregate as required, and rerolling such areas. The compacted coarse aggregate should present a firm, even surface, true to specified cross section and parallel to the finished grade, and have a texture which will allow a uniform penetration of the bituminous material.

88. Removing Forms

After the coarse aggregate has been satisfactorily compacted, and prior to applying the bituminous material, forms must be removed so that the spaces may be filled with shoulder material and thoroughly compacted.

89. Test for Thickness of Coarse Aggregate

After the coarse aggregate has been spread and rolled, and prior to the application of bituminous materials, tests of the depth should be made. In general, a series of three test holes each should be dug at intervals of 200 feet, one test hole at the center and one at each quarter point. Deviations in excess of ⅜ inch or more should be corrected by loosening the surface, removing or adding macadam aggregate, and rerolling. Wooden blocks equal in height to the desired thickness of the first course may be placed on the base course at short intervals prior to spreading the aggregate to control thickness of the course.

90. First Application of Bitumen

A heavy application of bitumen is required to waterproof the macadam aggregate and hold it in place. The bituminous material should be applied uniformly with a bituminous distributor as shown in figure 46. The rate is usually about 0.75 gallon per square yard per inch of compacted thickness for heavy traffic. For lighter vehicles, the rate can be increased up to about 1.10 gallons per square yard per inch of compacted thickness. The bitumen should be applied only when the coarse aggregate is thoroughly dry throughout its entire depth. Bitumen should be applied at the recommended spraying temperature for bitumen used (table X). Unless the distributor is equipped to distribute the bitumen evenly at the junctions of application, building paper should be spread on the surface back far enough from the ends of each application so that uniform application may be started and stopped on the paper, and so that all sprays will operate properly on the entire length being treated. The building paper used for this purpose should be immediately removed and burned. A narrow spout pouring pot or hose attachment to the distributor should be used to apply bituminous materials for touching up all spots unavoidably missed by the distributor.

91. Protection of Surrounding Area

During all applications of bituminous material, adjacent structures and trees should be protected to prevent their being spattered or marred. All surplus bituminous material on the shoulders should be removed or blotted with fine sand before rolling begins so that the shoulder may be rolled with the wearing course.

92. Application of Keystone

Immediately following the first application of bituminous material, clean, dry, keystone of the gradations shown in table II should be spread evenly over the bituminous material in a sufficient amount to nearly fill the surface voids of the coarse aggregate. The size of the aggregate and the rate of application are determined by the size and number of voids to be filled in the top of the layer of coarse aggregate. Usual rate of application is about 25 to 35 pounds per square yard. Keystone should be spread from trucks moving backward, with aggregate spreaders, or by hand with shovels from stockpiles adjacent to the area to be treated. In no case should the aggregate be dumped on the areas to be treated. Aggregate must be spread ahead of the wheels of the trucks or spreader equipment, so that the bituminous material will be covered before the wheels pass over it.

93. Brooming and Rolling

The aggregate should be broomed with push brooms or drag brooms to obtain uniformity of spread. Rolling of the surface must start immediately after the spreading and smoothing of the keystone and while the bituminous material is still warm. Rolling should be done in the manner described in paragraph 87. Additional keystone should be broomed in the voids as the rolling progresses until the surface voids are uniformly filled without covering the coarse aggregate itself, and until the surface is uniform in texture. Rolling should continue until the course is firmly bound together and even, and shows no perceptible movement under the roller.

94. Second Application of Bitumen

After the first application of keystone has been rolled, the surface should be swept clean of all loose keystone, and the bituminous material for the second application should be applied to the surface uniformly as described in paragraph 90. The rate of application is to be determined by the size of chokestone, usually 0.8 to 1.0 gallons per 100 pounds of aggregate, the rate decreasing as the estimated traffic increases.

95. Application of Chokestone

Immediately following the second application of bituminous material, a layer of clean, dry, chokestone should be spread uniformly over the surface in the manner described in paragraph 92. A portion of the chokestone may be retained and then added as required while brooming and rolling are in progress. Brooming and rolling should be done as outlined in paragraph 93 and should continue until all surface voids in the coarse aggregate are completely filled and until the surface is uniform in texture, thoroughly bonded throughout, and shows no perceptible movement under the roller. Tandem rollers may be used for first rolling, but the speed of the roller should not exceed 3 miles per hour. Faster rolling develops waves that are difficult or impossible to remove.

96. Surface Treatment

If the pavement is to be used as a final wearing surface, a single surface treatment, described in paragraphs 70 through 80, may be used to provide a smooth, waterproof surface. RC is usually used as the bitumen. The grade used would depend upon the surface and weather conditions. Rate of application is about 1 gallon of bitumen for 100 pounds of aggregate. To complete the surface treatment, a one-stone thickness of coverstone is spread over the bitumen, and the surface is drag broomed and rolled with a 5- to 8-ton roller. Instead of surface treatment, a 1-inch layer of hot plant mix, described in paragraphs 113 through 134 may be placed over penetration macadam for a more durable surface.

97. Surface Requirements

The final surface should be true to specified line, grade, and cross section. Portions of the pavement that are defective in composition or that deviate from requirements should be replaced or readjusted with suitable material.

98. Protection and Maintenance of Pavement

Before the surface treatment is applied, the pavement should be protected from all traffic other than that absolutely essential for its construction. During the 10-day period immediately following completion of the surface treatment, the finished pavement should be rolled and drag broomed. Fat spots or other defective areas that appear should be corrected.

Section VI. ROAD-MIX (MIXED-IN-PLACE) PAVEMENT

99. Introduction

Road-mix pavements consist of mineral aggregate and mineral filler uniformly mixed in place with a bituminous material and compacted on a prepared base course or subgrade. A single layer, about 1½ inches to 3 inches thick, is usually used. This type of pavement is likely to become defective unless it has a sound, well-drained subgrade and is well mixed, uniformly spread, and compacted. Road-mix pavements may be used as a wearing surface on temporary roads and airfields and as a bituminous base or binder course in stage construction of more permanent-type roads and airfields. Road mix is an economical method of surfacing small areas when aggregate can be used from the existing base or when satisfactory aggregate is nearby.

100. Materials

a. Bituminous Materials. For road-mix pavements, the grade and type of bituminous material depend on the aggregate, equipment available, and the weather. Recommended types and viscosity grades of bituminous materials suitable for road mix are shown in table I. These are asphalt cutbacks, asphalt emulsions, and road tars. A medium-curing cutback is usually used in a moderate climate; a slow-curing cutback is usually satisfactory for cold climates. Viscosity is controlled by the temperature, aggregate gradation, and the method of mixing. The highest viscosity that will completely and uniformly coat the particles of aggregate should be used. In general, open-graded aggregate requires a higher viscosity; a gradation containing mineral filler requires a less viscous grade.

b. Aggregate. Aggregate used in road mix may be scarified from the existing subgrade or base or hauled in from a nearby source. A wide range of gradations of coarse and fine aggregate and mineral filler may be used. Recommended gradation limits are shown in table II and the suggested bitumen content for each gradation is shown in table VIII. After the aggregate is blended in the windrows, samples should be taken for a sieve analysis. Gradation of the aggregate shown in table VIII may be changed to meet specific field conditions. Acceptable deviation is as follows:

Table VIII. Suggested Bitumen Content for Each Gradation for Road-Mix Wearing Surfaces *

Gradation number	Percent bitumen (by weight)
17–A	5.0–8.0*
18–A	5.0–8.5*
19–A	5.0–9.0*

* The average of percentage shown represents the maximum and minimum contained in the mix after exaporation of the lighter constituents.

Aggregate passing the No. 4 sieve --- 7 percent plus or minus

Aggregate passing the No. 30 sieve -- 5 percent plus or minus

Aggregate passing the No. 200 sieve - 2 percent plus or minus

The ideal aggregate for road-mix pavements is a well-graded (dense or open) sandy gravel or clean sand. Maximum size of the aggregate, in general, is limited to two-thirds of the compacted thickness of the layer. Loose thickness is approximately 1¼ times desired compacted thickness. A test for moisture content should be made before the aggregate is mixed with asphalt cutbacks or road tars. If the aggregate is too wet, it should be worked with mechanical mixers, graders, or improvised plows to allow the excess moisture to evaporate. For cutbacks and tars, moisture content of coarse-graded aggregate should not exceed 3 percent and of fine-graded aggregate, 2 percent. For emulsions, moisture content of coarse-graded aggregate should not exceed 5 percent and of fine-graded aggregate, 3 percent.

101. Proportioning the Mix

Quality of the road-mix pavement depends on control of the mix. The percentage of bitumen shown in table VIII will vary in relation to the absorptive quality of the aggregate, rate of evaporation of the volatile substances, and other factors. Although an exact formula is difficult to follow, proportioning must be controlled within very narrow limits to assure the stability and life of the mix. With dense-graded aggregates especially, too much bitumen should not be used. If equipment is available, the Modified Marshall Method (TM 5–530) will be used to establish trial bitumen content. All particles of the completed mix should be coated and uniform in color. If the mix is too lean, the aggregate in the windrow will stand almost vertical. If it is too rich, it flows readily to re-established shape. If the mix is correctly proportioned, a handful squeezed into a ball retains its shape when the hand is opened.

102. Construction Procedure

Road-mix pavements should be constructed only on a dry base when the weather is not rainy. Atmospheric temperature should be above 50° F. Initial construction procedure depends on whether the base is a newly constructed base, a scarified existing base, or an existing pavement. Figure 51 shows the sequence of operations for a typical road-mix project.

a. Newly Constructed Base. If a newly constructed base is used, apply the following procedure:

(1) Inspect and recondition the base.
(2) Prime the base and allow prime to cure.
(3) Place (or import) and windrow the aggregate at the side of the primed base (allow aggregate to dry).
(4) Spread the aggregate on the cured primed base.
(5) Spread the bitumen on the aggregate in increments of about one-third the total amount required.
(6) Mix the bitumen with the aggregate, blade, and aerate.
(7) Spread the mix to specified uncompacted thickness.
(8) Compact the surface.
(9) Apply seal coat if necessary.

b. Scarified Base. The aggregate is scarified from a base if it is unavailable from other sources. Procedure is as follows:

(1) Loosen the aggregate from the base.
(2) Dry and break up all lumps of material.
(3) Blade into parallel windrows of uniform size at one side and/or in the center.
(4) Inspect and recondition the base.
(5) Sweep the base.
(6) Prime the base and allow time to cure.

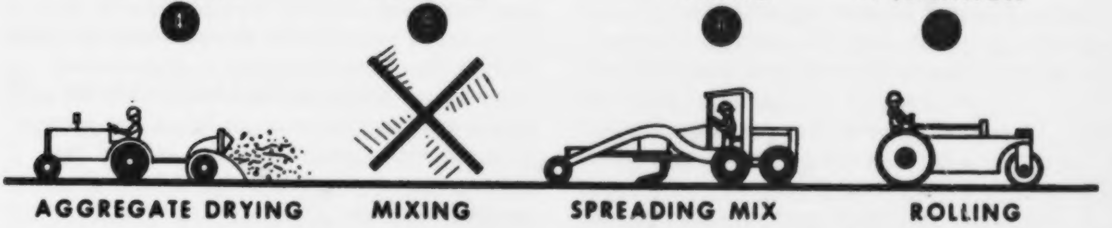


Figure 51. Sequence of operations for the construction of a typical road-mix pavement. (From "Bituminous Construction Handbook," courtesy of Barber-Greene Company.)

(7) Spread the aggregate on the cured primed base.

(8) Continue as directed in *a*(5) through (9) above.

c. Existing Pavement as a Base. If an existing pavement is used as a base, the procedure is:

(1) Sweep the base.

(2) Apply a tack coat and allow to cure.

(3) Bring in the aggregate and deposit in windrows at the side of the cured, tacked base.

(4) Dry the aggregate.

(5) Spread the aggregate on the tacked base.

(6) Continue as directed in *a*(5) through (9) above.

103. Base Preparation

The base course should be inspected and tested for criteria given in paragraph 58, and deviations should be corrected. Ruts or soft, yielding spots in the base course should be corrected by loosening, removing, or adding material, and recompacting to line and grade. Line and grade should be maintained with grade stakes or steel pins, placed in lines parallel to the centerline of the area to be paved and spaced so that stringlines may be stretched between them. A prime coat, described in paragraphs 57 through 64, should be applied to the base.

104. Placing and Windrowing the Aggregate

a. Hauled-In Aggregate. Aggregate for the road mix on a base or an existing pavement used as a base should be hauled to the paving site in trucks equipped or supplemented with suitable spreading devices and deposited on the base course or subgrade. Bottom dumps or scrapers also could be used for hauling. The amount of aggregate and mineral filler should be proportioned by weight as described in paragraph 100, or by volume. The aggregate and mineral filler should be thoroughly mixed by windrowing and turning with a blade grader. It should then be bladed into uniform windrows in sufficient quantity and proportion to provide a finished course of the specified thickness. Care should be exercised to prevent the aggregate from becoming mixed with the shoulder material, segregated in pockets, or mixed with the subgrade, subbase, or base material.

b. Scarified Aggregate. When the aggregate is obtained from the existing base, test bores are made along the proposed road or runway to determine whether enough aggregate is available for the job and whether use of the aggregate will affect the bearing qualities of the remaining subgrade. Then the base is scarified to the required depth, the loosened material is mixed by harrows and graders to break all the lumps, and the aggregate is finally bladed into parallel windrows of uniform size at the side and/or center of the paving area. If it is necessary to blend material with the scarified base to improve the gradation or increase the thickness, the new material is dumped and spread evenly, either before or after scarifying. If a prime coat is required on the top of the uncovered base, it is applied to the spaces between the windrows and allowed to cure. The windrows are then bladed to the cured primed strips and the remaining strips of the base are primed.

105. Windrow Specifications for Dry Aggregate

Windrows reduce loss of the aggregate from the base through the action of traffic and reduce the amount of moisture that will be absorbed during wet weather by aggregate spread but not compacted. Windrows should have a cross-sectional area of 6 to 10 square feet for ordinary construction equipment, or 10 to 14 square feet for a travel plant.

106. Mixing

Travel plant and blade mixing are discussed below. Cutback asphalts require heating to temperatures ranging from 80° F. to 200° F. for suitable spraying and mixing fluidity. Asphalt emulsions are applied at temperatures of 50° F. to 120° F., and tar from 80° F. to 225° F.

a. Travel Plant Method. When a travel plant is used, the loose aggregate is dumped, mixed, and bladed into uniform windrows and evened if necessary. Figure 43 shows the loose aggregate being formed into windrows with an improvised windrow box. The windrow should be sufficient to cover the section of the area to be paved with enough loose material to give the desired compacted depth and width. As the bucket loader tows the mixer and elevates the aggregate to the mixer hopper, the mixer meters the aggregate, sprays it with the correct amount of bitumen, mixes these two homogeneously, and redeposits the mix into another windrow behind the plant. The rate of travel and the mixing operation should be controlled so that all particles of the aggregate are coated and the mix is homogenous. Accuracy in proportioning the mix is extremely important. An excess or deficiency of bitumen or uneven distribution should be corrected by adding bitumen or aggregate, and remixing. The travel plant method usually produces a more uniform mix of higher quality than blade mixing. Heavier types of asphalt cutback and tar may be used. This reduces the time required for curing. The asphalt finisher may be used concurrently with the travel plant. The hopper of the finisher is kept directly under the travel plant output chute. This arrangement greatly reduces the maximum output of the plant. Windrows must contain no more material than the finisher can place. The major advantage of this setup is that in-place aggregate may be used in an intermediate-type mix and placed with a finisher without the necessity of loading and transporting aggregate. The finisher must be used with the travel plant for construction of some airfields where surface tolerances are critical. Figure 52 shows a travel plant mixing a road-mix pavement at an airfield construction site.

b. Blade Method. After the dry aggregate has been bladed into windrows, the windrows are flattened and bitumen of the specified temperature is applied with a bituminous distributor in two or more equal applications. Each application is usually from 0.3 to 0.5 gallon per square yard. Immediately following each application of the bituminous material, the treated aggregate should be mixed with springtooth or double-disk harrows, graders, rotary tillers, or a combination of them, until all the particles of the aggregate are evenly coated. When motor graders are used, the windrow is moved from side to side by successive cuts with the blade. Mixing with a motor grader is shown in figure 53. Several graders can operate, one behind the other, to reduce the time required for complete mixing. In hilly terrain, blading tends to drift the mix downhill, permitting an excess to accumulate at the bottom. After all of the aggregate has been mixed, the mix should be bladed into a single windrow at or near the center of the road, and turned not less than four complete turns from one side of the road to the other. Excess bitumen, deficiency of bitumen, or uneven distribution should be corrected by the addition of the required amount of aggregate or bituminous material, followed by remixing. Mixing should continue until it is com-

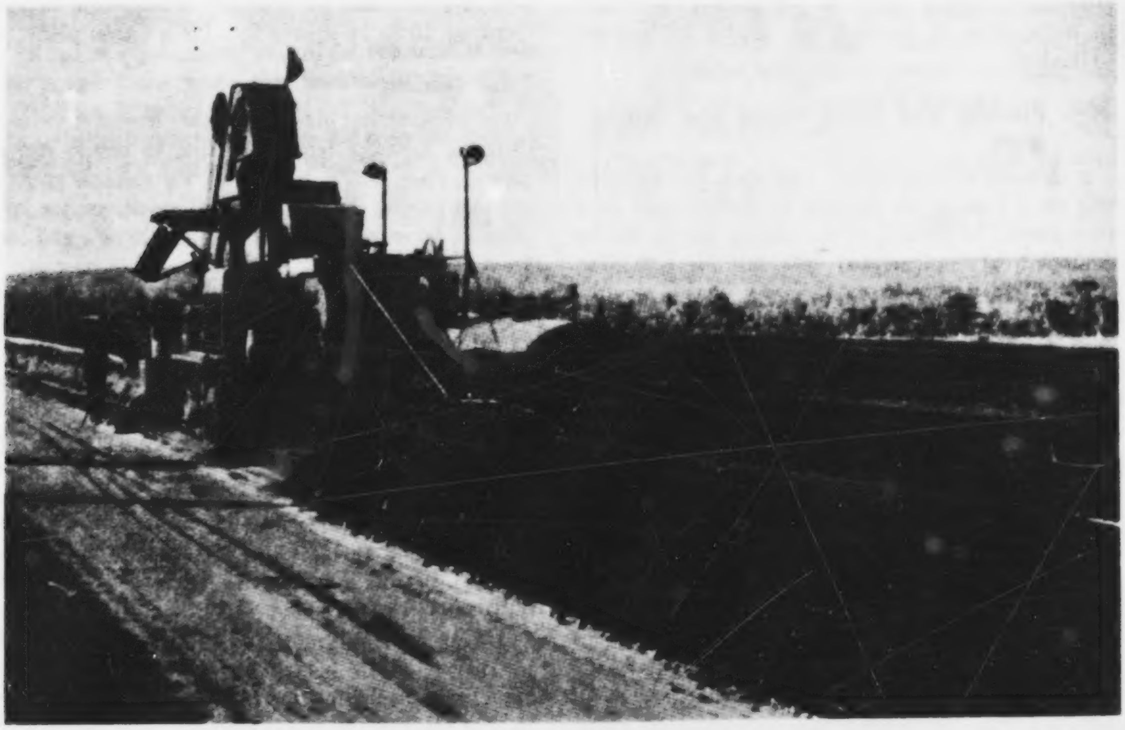


Figure 52. Typical travel plant mixing a road-mix pavement at an airfield site.

plete and satisfactory. If the materials, weather conditions, and equipment are well suited to mixed-in-place paving but the road or airfield must carry traffic as soon as possible, the windrowing of aggregate and the mixing and the spreading of bitumen may be done elsewhere on any area of smooth ground which can be compacted for the purpose, or on any unused road or airfield surface. The road or airfield surface to be paved is then primed or tacked if necessary. As soon as the prime or tack coat cures, the bituminous mix is picked up, trucked to place, dumped at proper intervals, and then bladed into windrows ready for spreading (fig. 54).

107. Procedure for Thickened Edges

When a thickened edge of surfacing is specified, a triangular cut conforming to the specified dimensions should be made with a motor grader blade at each edge of the surfacing. The excavated material should be thrown to the shoulder in a small windrow against which the mixture is to be spread. The trench should be primed in accordance with paragraphs 57 through 64, prior to spreading of the bituminous mix. The trench cut by the grader should be filled with bituminous mix. This layer is thoroughly rolled with a roller, then the surface course is spread.

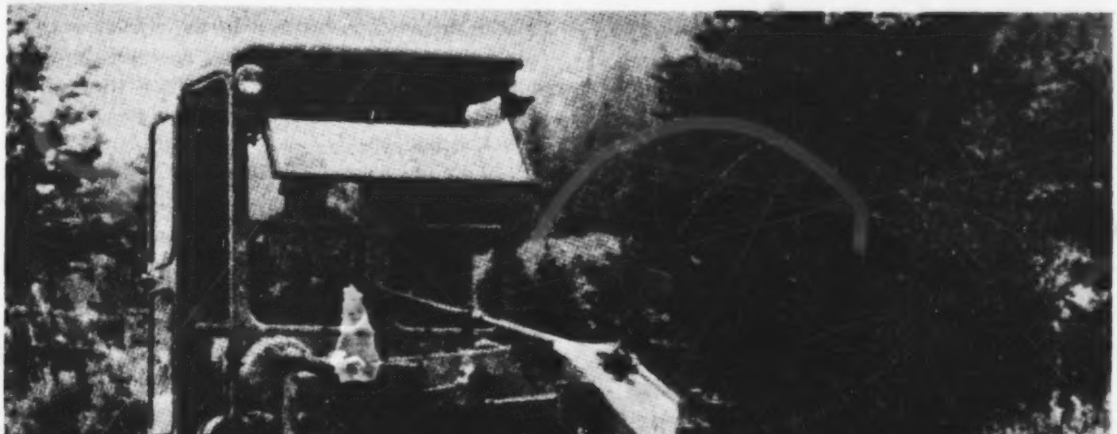


Figure 53. Mixing (blading) road mix with a motor grader.

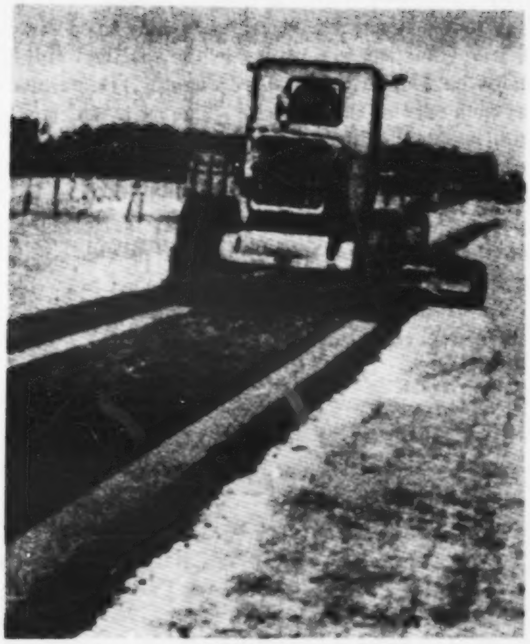


Figure 54. Spreading road mix with a motor grader.

108. Spreading and Shaping

a. The bitumen and mineral aggregate, after being satisfactorily mixed and aerated, are spread from the windrow upon the base course in a layer of uniform thickness conforming to established line and grade. Spreading should not be started until an inspection is made of the subgrade or base course and any necessary reconditioning has been completed. The bituminous mix should not be spread when the surface is damp, or when the mix itself contains moisture in excess of that specified in paragraph 100*b*. The mixed material should be spread to the required width in thin, equal layers by a self-propelled blade grader, finisher, or other equipment. (If a finisher is used, additional support equipment is required, and the material must be split into two windrows for an 8- to 12-foot wide pavement.) When spreading the mix from a windrow, care should be taken to prevent cutting into the underlying subgrade or base course. If necessary to prevent such cutting, a layer of mix, approximately ½-inch thick, may be left at the bottom of the windrow.

b. The material spread should be rolled once, and then leveled with a blade grader to remove inequalities. The remaining material should then be spread and rolled in thin layers, until the entire mix is evenly spread to the depth and width specified. During the spreading and compacting, the surface should be dragged or bladed, as necessary, to fill any ruts and to remove corrugations, waves, or other irregularities. A multiple-wheel pneumatic-tired roller may be used for the early stages of rolling.

109. Rolling Finished Surface

After all layers have been satisfactorily spread, the surface should be rolled with tandem rollers (fig. 55). Rolling should begin at the outside edge of the surface and proceed to the center, overlapping on successive trips at least one-half the width of the wheel of the roller, Alternate trips of the roller should be of slightly different lengths. The speed of the roller at all times should be controlled to avoid displacement of the mix. Light blading (or floating) of the surface with a patrol grader during the rolling period may be required. Rolling should be continued until all roller marks are eliminated, and maximum density obtained. To prevent adhesion of the mix to the roller, the wheels should be moistened; but too much water should be avoided. The rollers should be in good condition, suitable for rolling asphalt, and should be operated by trained roller operators. At all places not accessible to the roller, the mix should be thoroughly tamped with hand tampers. If the surface course becomes rough, corrugated, uneven in texture, or traffic marked, unsatisfactory portions should be torn up, reworked, relaid, or replaced. If any portion of the surface, when laid, becomes water soaked for any reason, that portion should be torn up at once, and the mix therefrom placed in a windrow and aerated until its moisture content is within the limits specified, and then spread and rolled.

110. Shaping Edges

When forms are not used, and while the surface is being compacted and finished, the outside edges should be trimmed neatly to line, if time permits.

111. Sampling Pavements and Mixes

Samples of the mix should be taken and tested for every 400 tons of mixed aggregate or fraction

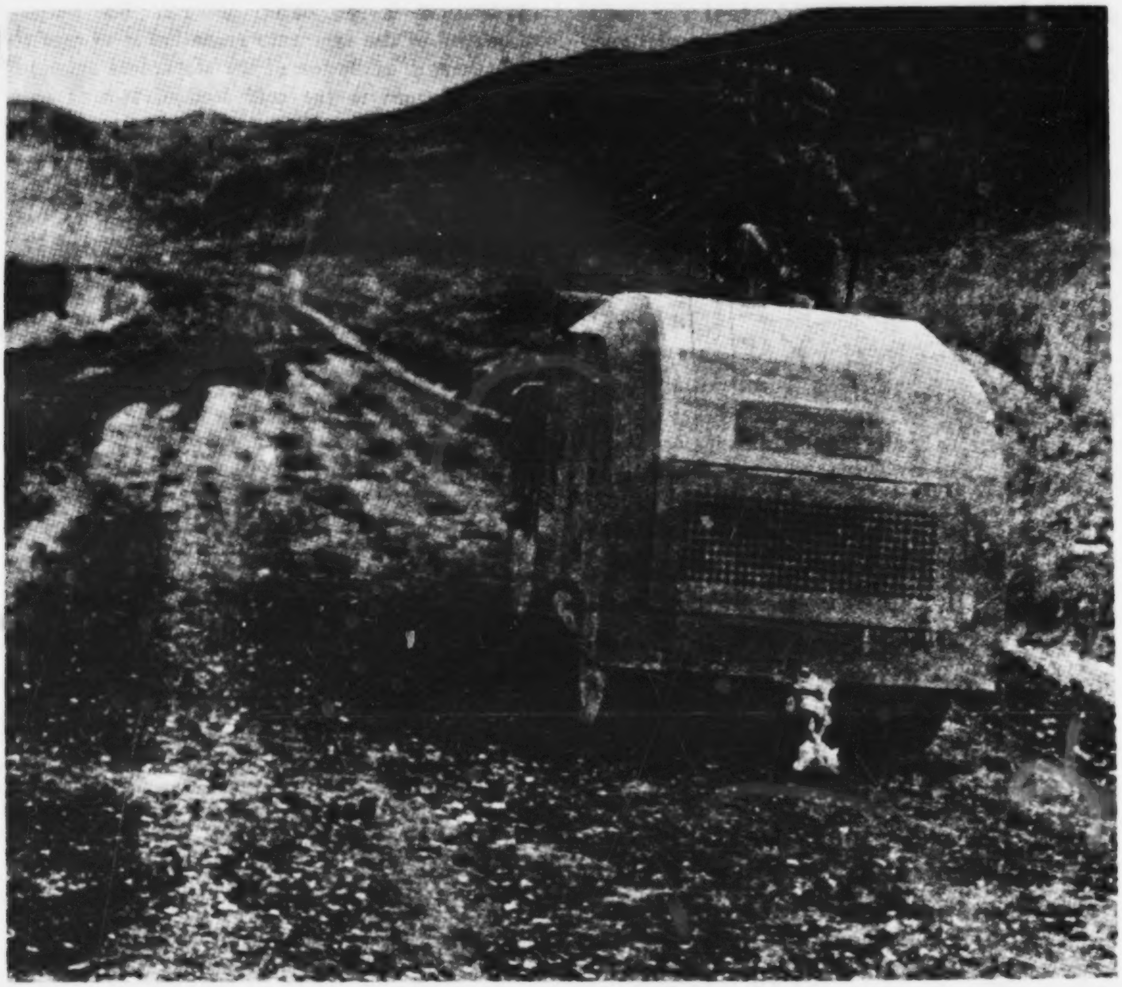


Figure 55. 5- to 8-ton roller compacting a bladed road mix.

thereof to determine gradation and percent of bitumen, thickness, and density of the completed wearing surface. If the deficiency in composition, density, and thickness exceeds the requirements specified, such material should be removed and replaced.

112. Surface Treatment

If the road-mix surface course is constructed from an open-graded aggregate, a surface treatment may be required to waterproof the surface. A surface treatment is unnecessary on a dense-graded, well-compacted, road-mix pavement.

Section VII. PLANT MIX

113. Introduction

Plant mix is a mixture of mineral aggregate and bitumen mixed in a central plant. Proportioning of aggregate and bitumen is closely controlled and the mineral aggregate is usually dried and heated before mixing. The mixed material is transported to the site, spread, and compacted. The mixing plant generally consists of portable units that may be assembled in various combinations. Various types of central plants are discussed in paragraphs 35 through 38. Plant-mix pavement is usually superior to mixed-in-place or penetration macadam pavement because a heavier grade of bitumen can be used and control of proportioning and mixing is more effective.

114. Central Plant Layouts

Different central plant setups are used so that a mix can be produced with the required degree of accuracy and economy that is compatible with the type of road or airfield under construction. Recommended plant layouts are illustrated in TM 5-337-1.

a. Central Plant Without Dryer and Gradation Control Unit. The central plant without dryer and gradation control unit is the most simple of the central plant setups and is most commonly associated with cold mix and stabilisation work. It consists only of the mixer and such auxiliary equipment as may be required to heat the bitumen and feed the aggregate and bitumen to the mixer. The aggregate flow through the plant is simple. The aggregate is moved directly from the stockpile to the mixer where the aggregate and bitumen are accurately proportioned, mixed in the pugmill, and discharged into waiting trucks.

b. Central Plant With Dryer and Without Gradation Control Unit. The central plant with dryer and without gradation control unit gives positive control of the moisture content of the aggregate but does not control gradation of the aggregate. The dryer drives off the moisture and heats the aggregate to the proper mixing temperature for either hot mix or cold mix, and the mixer accurately proportions and blends the bitumen and dried aggregate. For cold mixes, the hot aggregate frequently must be permitted to cool before mixing. A belt conveyor is normally used for cooling between the dryer and the elevator feeding the mixer. The aggregate is fed to the dryer cold elevator by a cold-feed system using a reciprocating feeder. The second elevator feeds the mixer and is enclosed to retain the heat.

c. Central Plant With Dryer and With Gradation Control Unit. The central plant with dryer and gradation control produces high-type bituminous mixes. A flow diagram of the 80- to 120-TPH high-type plant is shown in figure 17. Figure 18 shows the same type of central plant in operation. Screens and bins for gradation control are inserted between the dryer and the mixer. The degree of control depends upon the number of fractions into which the aggregate is divided. The usual number of divisions is two, three, or four. The purpose of control of the aggregate gradation is to regulate variations in gradation of the stockpiled aggregate and variations in the cold feed of two or more aggregates. The use of multiple-aggregate cold feed is a form of gradation control, but the degree of accuracy necessary for high-type mixes cannot be assured when using that method only. Screening and grading take place after the aggregate has been dried so that screens will not clog, and segregation that may take place in the stockpile or in the plant is corrected immediately prior to mixing the aggregate and bitumen.

115. Types of Plant Mix

a. Hot-Mix Bituminous Concrete Pavements. Hot-mix bituminous concrete mixed in a high-type control plant is a mix generally composed of well-graded mineral aggregate, mineral filler, and bituminous cement. It is particularly suitable for surfacing airfields that will be used by heavy planes or for heavy-duty-traffic roads and streets. It also is used for base and binder courses.

(1) To prepare hot-mix bituminous concrete, the aggregates are thoroughly dried, heated, accurately proportioned, and mixed with bitumen at a temperature of about 250° to 350° F. in a liquid form and at a specified rate. The mix is spread by an asphalt finisher or by hand methods, where the finisher cannot be used, and while still hot (about 250° F.), is compacted to the required density and thickness with power rollers. Hot mixes lose their workability when cooled to air temperature. The hot-mix method assures that the aggregate is coated with a uniform film of bitumen and that the size of the aggregate and quantity of bitumen are accurately controlled. Hot-mix pavements do not require a curing period. They can be used as soon as the pavement has been compacted to required density and cooled. They can be constructed rapidly with minimum probability of damage to unfinished pavements from unfavorable weather conditions.

(2) Immediately after adequate rolling and an adequate cooling period, the pavement has high stability and high resistance to damage by moisture penetration. The surface is durable, waterproof, and homogenous in character. Hot-mix wearing sur-

PROBABLE CAUSES OF DEFICIENCIES IN HOT PLANT MIX PAVING MIXTURES		TYPES OF HOT MIX TROUBLE									
ITEM		ASPHALT CONTENT FAILS TO CHECK JOB MIX FORMULA	GRADATION FAILS TO CHECK JOB MIX FORMULA	POORLY MIXED LOADS	FAT, RICH MIXTURES	LEAN OR BURNED MIXTURES	MIXTURE TEMPERATURE FAILS TO CHECK JOB MIX	SMOKING LOADS	STEAMING LOADS	OVERWEIGHT OR UNDERWEIGHT LOADS	LACK OF UNIFORMITY OF MIXTURES IN LOADS
1	AGGREGATE SCALES OUT OF ADJUSTMENT	X	X		X	X					
2	BRIDGING OF HOT AGGREGATE IN BIN		X							X	X
3	BITUMEN SCALES OUT OF ADJUSTMENT	X			X	X				X	X
4	LACK OF PROPER WEIGHING BY OPERATOR	X	X		X	X				X	X
5	FAULTY PUG MILL DUMP GATE	X	X	X	X	X				X	X
6	BITUMEN TEMPERATURE TOO HIGH			X	X	X	X				X
7	DRUM FEED NOT UNIFORM						X	X	X		
8	IMPROPER DRYER OPERATION					X	X	X	X		
9	TOO LITTLE BITUMEN	X				X					X
10	TOO MUCH BITUMEN	X			X						X
11	SAMPLING METHOD NOT UNIFORM	X	X		X	X					
12	EXCESSIVE MOISTURE CONTENT OF AGGREGATE								X		X
13	BIN OVERFLOW PIPES NOT FUNCTIONING	X	X								X
14	LEAKY BINS	X	X		X	X					X
15	SEGREGATION OF AGGREGATES IN BINS		X								X
16	MIXING TIME NOT UNIFORM	X		X							X
17	MINERAL FILLER FEED NOT UNIFORM	X	X		X						X
18	AGGREGATE TEMPERATURE NOT UNIFORM					X	X	X			
19	TEMPERATURE MECHANISM TOO HIGH					X	X	X	X	X	X
20	IMPROPER FEED OF AGGREGATES OUT OF ADJUSTMENT	X	X		X	X		X	X		X
21	OVERRATED DRYER CAPACITY						X		X		X
22	FAULTY SCREEN OPERATION		X								X
23	OVERLOADED PUG MILL			X							X
24	IMPROPER SET ON PUG MILL	X	X	X							X
25	BITUMEN AND AGGREGATE FEED OUT OF ADJUSTMENT	X	X		X	X					X
26	BITUMEN PUMP NOT FUNCTIONING PROPERLY	X			X	X					
27	NOT SUFFICIENT HOT AGGREGATE IN STORAGE BINS	X	X								X
28	AGGREGATE GATES NOT PROPERLY SET	X	X		X	X					X

TYPES OF DEFICIENCIES THAT MAY BE ENCOUNTERED IN PRODUCING HOT PLANT MIX PAVING MIXTURES

ITEMS 6 TO 23 INCL. ARE APPLICABLE TO ALL TYPES PLANTS. ITEMS 1 TO 5 INCL. AND ITEMS 24 TO 28 INCL. ARE APPLICABLE TO BATCH PLANTS AND VOLUMETRIC PLANTS RESPECTIVELY.

Figure 56. Deficiencies of hot plant mix and probable causes.

faces must be laid over a base course constructed to provide structural stability and distribute the wheel load over the subgrade. The highest type of bituminous pavements are constructed from hot-laid mixes made with asphalt cement, known as asphaltic concrete, tar concrete, sheet asphalt, and stone-filled sheet asphalt, according to the grading of mineral aggregate and bitumen used. (Special mixes are discussed in paras 135–139.) Hot mixes are recommended for use whenever equipment, materials, and men are available. Deficiencies of hot plant mixes and probable causes are shown in figure 56.

b. Cold-Laid Bituminous Plant Mix. Cold-laid asphaltic concrete pavements are composed of a mix of asphalt cement and liquefier, asphalt cutback or asphalt emulsion, and generally a well-graded mineral aggregate. Cold-laid mixes are mixed in a central plant and spread at atmospheric temperatures. The aggregate is heated only for drying, but the bitumen must be heated to the necessary workability to coat the aggregate thoroughly. The term cold-laid bituminous plant mix is a broad one covering a wide variety of types and grades of bitumen and of aggregate gradations. The aggregates used are usually the same as those used for hot-mix asphaltic concrete. Cold-laid plant mix is similar to hot-mix bituminous concrete in appearance and general physical characteristics, but is less durable.

(1) Disadvantages of cold-laid plant mix pavement are that a curing period is required to permit evaporation of excess moisture and of the volatile substances contained in the bitumens of the liquefier. High density is difficult to secure in cold weather by rolling, and initial stability is likely to be low. Cold-laid bituminous concrete pavements are used for roads and streets, but they are unsatisfactory for airfields. They are especially suitable for patchwork and construction of small jobs where the tonnage to be used does not justify the erection of a hot-mix plant.

(2) Advantages are that they can be manufactured at a central plant, shipped by rail or truck to the paving site, and produced in small quantities.

(3) One type of cold-laid bituminous plant mix is composed of graded mineral aggregate and RC–250 or RC–800. The quantities of bitumen required are determined by the Modified Marshall Method (TM 5–530). Another type of cold-laid bituminous plant mix is prepared with aggregates containing not over 2 percent moisture sprayed with a liquefier and asphalt cement of 85 to 100 penetration. The curing period can be reduced by regulating the amount of liquefier used. The slow-curing grades of asphalt and RT–5 through RT–9 also are used for cold-laid plant mix. Cold-laid plant mixes may be spread either by blade graders or by mechanical spreaders. Spreading by blade graders is identical to the procedure outlined for spreading road mix discussed in paragraph 106*b*. Spreading by mechanical spreaders is performed in the manner outlined in paragraph 122*b* for hot mixes. Cold-laid pavements are rolled in accordance with the procedure given for road mix in paragraph 109.

116. Materials

Bituminous materials recommended for use in hot-mix and cold-laid pavements are listed in table I. Aggregate gradations for the various types of hot-mix surface and binder courses are listed in table II. Graphs for the data in table II are shown in appendix IV. Aggregate gradations for cold mixes may be the same as for hot mixes or identical to those used for road mixes given in table II.

117. Hot-Mix Laydown

The sequence of operations given below is applicable, in general, to hot-mix laydown. Because of the varied conditions for each job, however, other procedures may prove equally satisfactory. Operations are discussed in paragraph 118 through 134. Figure 57 shows the sequence of operations for the placement of a hot-mix pavement.

a. Sweep the base.

b. Patch any cracks or holes if mix is to be placed on existing pavement.

c. Apply prime or tack coat. (Use tack coat over a prime coat only if the prime coat has become old and dirty.)

d. Cure.

e. Inspect the equipment.

f. Inspect and sample the mix.

g. Place and spread.

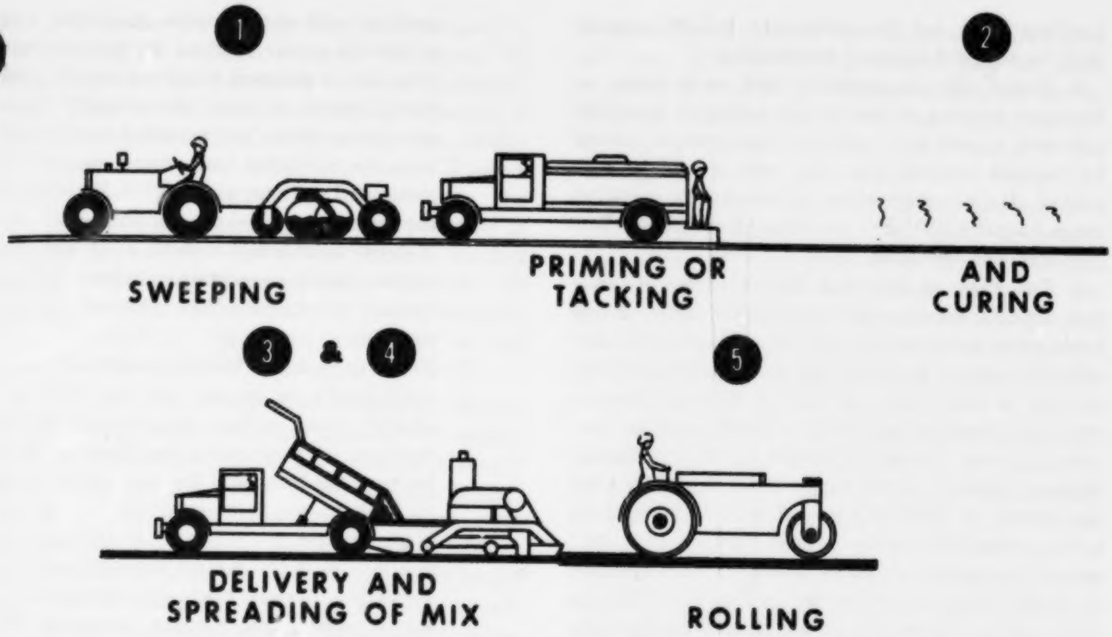


Figure 57. Sequence of operations for the placement of a hot-mix pavement.

h. Hand rake (where necessary).

i. Roll with three-wheel roller and check for conformance to grade requirements.

j. Roll with pneumatic-tired roller.

k. Roll with tandem roller.

118. Inspection of Equipment for Hot Mix

All vital items of construction equipment should be checked for compliance with specifications and for general adequacy and operating condition; adjustment, repair, or replacement should be made as necessary. In particular, the rollers and spreader should be checked. The screed on the spreader should be checked with a stringline for possible warping and for scoring. The screed setting should be adjusted to provide a properly leveled crown in those lanes that deviate from a plane surface. For lanes that require a level surface, the screed should be set approximately ⅛ inch high in the center, sloping uniformly toward both edges. This will prevent the surface from becoming slightly dished. The adjustment should be subject to modification based on straightedge depth tests on the completed pavement.

119. Placing Temperature of Hot Mix

Optimum placing temperature depends on the weather and on rolling characteristics of the mix. When this temperature has been determined, it should be maintained, plus or minus 25° F. (15° C.). Average heat loss between plant and spreader must be considered.

120. Inspection of Hot Mix

Each truckload of hot mix from the central plant should be observed when it arrives and when it is dumped. Temperatures should be taken often enough to assure compliance with requirements. Most mistakes in batching, mixing, and temperature control will be detected by visual observation. If only a portion of a truckload is rejected, the unsatisfactory material must be removed from the spreader hopper or from the grade and discarded.

121. Rejection of Hot Mix

Reasons for rejection of all or part of a truckload are given below.

a. Too Hot. Blue smoke rising from the spreader hopper usually indicates an overheated batch, and the temperature should be checked immediately. The batch should be discarded when the temperature exceeds the maximum specification requirement (usually 350° F.). A batch is not usually discarded when it exceeds the optimum temperature (usually 325° F.) without exceeding the specifications limit, but the equipment should immediately be adjusted to avoid overheating.

b. Too Cold. A generally stiff appearance or improper coating of the larger aggregate particles indicates a cold mix, and the temperature should be checked immediately. The mix should be discarded if the temperature is below the specified range (usually 250° F.), and immediate steps taken to correct the condition.

c. Too Rich. A mix that has an excess of bitumen usually may be detected immediately. When loads have been arriving at the spreader with the material peaked or domed up and a load suddenly appears in which material lies flat or nearly flat, it probably contains too much asphalt, and an immediate, close inspection should be made. Excess bitumen, likewise, is apparent under the screeds by the manner in which the mix slicks off. Sometimes a hot screed will cause a slick surface that will appear to contain too much bitumen. This appearance will disappear when the mix cools. When a slick surface occurs, the screed should be checked. If the screed is hotter than usual, the mix should be allowed to remain in place until it cools to determine whether the slick surface was caused by a hot screed or an excess of bitumen. If the slick appearance does not disappear, the mix should be removed and replaced.

d. Too Lean. A mix that contains insufficient bitumen usually may be detected immediately in the truck or spreader hopper by its lean granular appearance, improper coating of aggregate, less than ordinary slump in the trucks, and lack of the typical shiny black lustre, or by its action under the screeds.

e. Miscellaneous. Other obvious reasons for rejection of all or parts of a truckload of hot mix are excess fines, excess coarse materials, and nonuniform mixing.

122. Placing and Spreading Hot Mix

Placing and spreading a hot-mix bituminous concrete pavement consists of uniformly distributing the loose material on a completed base so that the specified thickness, line, and grade may be obtained.

a. Methods of Spreading. The three methods of spreading are hand, blade, and mechanical spreading.

(1) *Hand spreading.* Hand spreading, the oldest method, can be used where asphalt finisher is not available or at locations where the asphalt finisher cannot be used, such as adjacent to curbs, manholes, and at curved corner sections at intersections. The mix is dumped from the trucks onto dump boards or into conveniently sized piles from which the material is shoveled onto the prepared base, raked smooth to grade and contour, and rolled. Because of the amount of labor required and the inability to obtain a smooth, even textured surface, hand spreading is not used to any extent to supplement other spreading methods.

(2) *Blade spreading.* Motor graders are used occasionally to spread hot mix and reasonably good surface smoothness can be obtained by positioning the blade midway between the front and the rear and making multiple passes. Such successive pass of the blade reduces the reflection of the base irregularities in the surface through multiple correction. Because blade spreading usually leaves unsatisfactory edges, joints are seldom attempted. Instead, the mix is spread across the full width of the road at one time by an echelon of graders or by a sufficient number of passes of the same grader. Segregation of the mix may be caused by blade spreading methods. As the blade spreads out the windrow, the larger particles of coated aggregate fall toward the outside edge of the road. Like road-mix pavements, in hilly terrain, blading tends to drift the mix downhill, permitting an excess to accumulate at the bottom.

(3) *Asphalt finisher.* Figure 58 shows an asphalt finisher spreading the hot mix. The mix is dumped by trucks into a hopper at the front end of the finisher for subsequent placement on the road. When the mix is dumped into the hopper, both sets of truck wheels should be fitted firmly against the finisher bumper rolls which push the trucks. If a truck is turned so that the bumper rolls are pushed against one set of wheels only, the finisher tends to turn and continual correction is required by the operator which leaves irregular, ragged, and poorly compacted joints. A mix that clings to the sides of the hopper should be continually loosened to promote correct placement. When the mix is permitted to ac-

cumulate, it cools rapidly, and eventually a slug of semicold material will reach the grade. In comparison to blade spreaders, asphalt finishers have higher capacity, a smoother riding surface, and the ability to handle the stiffer hot mixes. When a load is deposited into the hopper, the coarse aggregate has a tendency to flow to the outside edges of the hopper, causing undesirable joints of coarse material. To prevent such joints, the coarse material should be pushed to the center of the hopper with shovels.

b. *Procedure for Mechanical Spreading.* Except when starting at a transverse joint butted against previously placed pavement, a wooden shim should be placed under the screed of the asphalt finisher (fig. 40). The shims should be the approximate uncompacted thickness of the course being placed. This permits the screed to start at the proper height and prevents dragging of the mix, causing ragged, uneven pavement and depth deficiencies. When starting from a transverse joint, metal strips of a thickness equal to the difference between the rolled and loose thicknesses of pavement may be used. At the beginning of placing operations, the screed should be heated to the approximate temperature of the mix. Frequently, during operations or if the work is stopped for more than a few minutes, the screed temperature should be checked and reheated to the desired temperature. The speed of spreading should not be so great as to tear or pull the surface. Pulling may result from operating the spreader too fast, from a wornout screed, tamping bars that are out of adjustment, a poorly graded mix, tearing from insufficient heat, or dirty screed to which the mix has adhered.

c. *Depth of Hot Mix.* Experience is important for placing the loose depth required for the specified compacted depth. Loose depth is roughly equal to compacted depth multiplied by 1.25. Loose depth should be measured with a depth gage at frequent intervals. At least three measurements should be taken across the lane. When paving is first begun, a sufficient number of measurements should be made to secure a good average loose

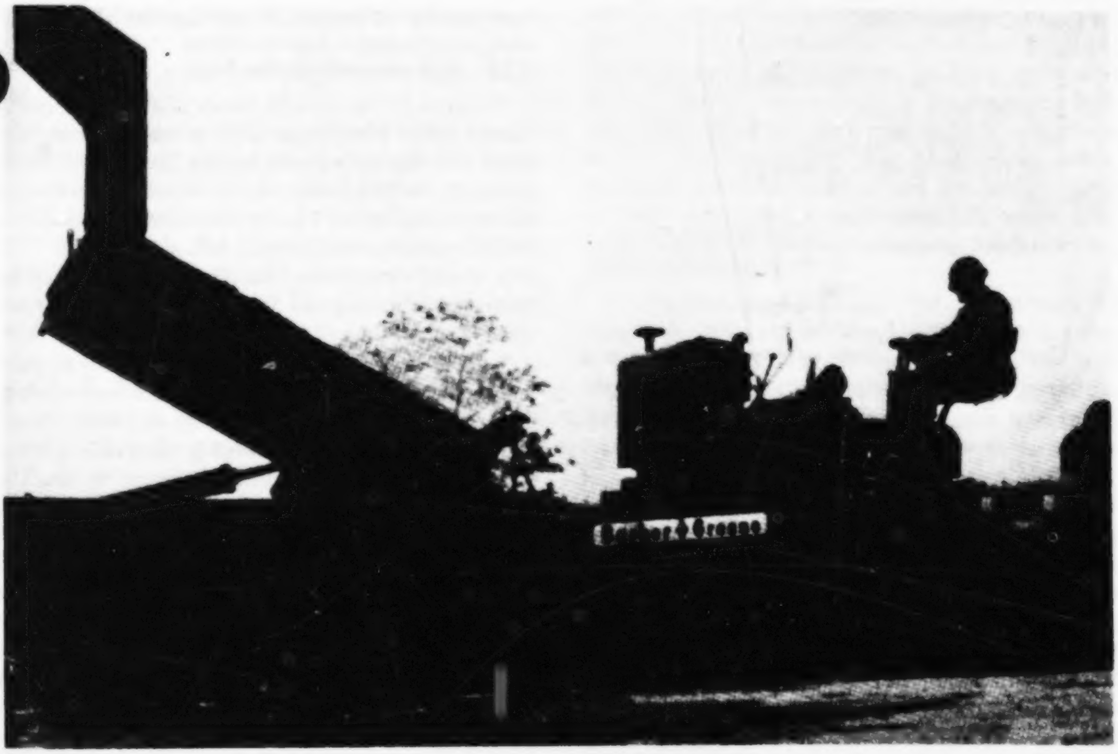


Figure 58. Model 879-A asphalt finisher placing hot mix.

depth determination. As soon as rolling is completed, sufficient depth tests should be made to provide a good average. When paving operations are well underway and progressing smoothly, it is better to rely chiefly upon yield checks and depth samples. The depth specimen should be cut carefully and removed from the hole without disturbing the base more than necessary. When the thickness of a specimen removed from the hole is measured, the specimen should be placed on a plane surface with the top down, a straightedge laid across the specimen, and measurement taken to the supporting surface. A quick depth check on either loose mix or finished pavement may be obtained by laying a straightedge on the surface overhanging the lane edge and measuring from the straightedge to the base or binder course.

123. Correction of Loose Depth

a. Computation of Depth Ratio. As soon as reliable loose and compacted average thickness values have been secured, a ratio should be established between these values for correction of loose depth. The example given below illustrates the method of computing loose depth.

Example:

Desired average finished depth = 1.50 in.
Average loose depth = 1.86 in.
Average compacted depth = 1.44 in.
Find the corrected loose depth.

Solution:

$$\text{Compaction ratio} = \frac{\text{Average loose depth}}{\text{Average compacted depth}}$$

$$= \frac{1.86}{1.44} = 1.29$$

$$\text{Corrected loose depth} = \text{Compaction ration} \times \text{Desired depth}$$

$$= 1.29 \times 1.50$$

$$= \mathit{1.94\ inches}$$

b. Adjustment of Screed. When starting the job or when resuming paving under different conditions, such as a change in thickness of course, the screeds should be reset where such action is clearly demanded by the depth tests. However, depth tests are only approximate and naturally represent pavement thickness only at the points tested. Screed adjustments should not be made every time a depth check does not yield the prescribed thickness. The finisher is designed to bridge irregularities in the base; thus, a thin spot in the hot-mix course could be covering a high point in the base. Frequent screed adjustments to maintain a preset depth wi accent irregularities in the base, yielding a no uniform surface. A more accurate check upon average pavement thickness is obtained by a constant close watch of the yield. Where yield is appreciably and consistently either high or low and the discrepancy cannot be accounted for otherwise, the screed setting should be adjusted accordingly.

124. Hand Raking

Hand raking of the hot mix after the mix is spread should be held at a minimum and used only to correct nonuniformity of grade or surface texture. Coarse material that is segregated in areas should be raked out, replaced with fresh hot mix from the hopper, and the fresh mix raked smooth. Coarse material which has been raked out in small quantities may be returned to the hopper. However, if the quantity is large enough to be noticeable as it comes through the paver, it should be wasted. It must not be cast over the fresh surface; such coarse particles cool rapidly and the rollers merely embed them into the course, leaving small surrounding pits. Any loose material along the edge of the lane should be pressed firmly against the edge.

125. Adjustments in the Mix

Changes in the mix in conformance with specifications and mix design criteria may be necessary when placing, rolling, and surface texture are unsatisfactory. Adjustments may be necessary even when the mix is uniform. The various conditions and corrective measures are outlined below.

a. Insufficient Fines. Insufficient fines should be corrected adjusting the job-mix formula to a finer gradation.

b. Mix Pulling and Checking. A mix that pulls under the finisher should be corrected immediately if the small open checks are not definitely closed during rolling. This condition is especially critical in the surface course. It may be caused by unsatisfactory proportioning of the mix, a mix that is too cold, or improper finisher operation. When the total fine aggregate is composed of stone screening and sand, an excessively high proportion of screenings may toughen the mix unduly. A tough mix is very desirable from the point of view of stability, but sometimes pulls badly. Even a small change in the percentage of fine aggregate may make an appreciable difference in placing and rolling characteristics, and frequently the percentage of sand may be increased without affecting the stability too greatly. If the condition is limited to surface checking and if the checking persists in spite of mix design changes, it may be corrected by scratching the surface lightly. One method that has been successful is to fasten stiff-bristled push brooms on a light timber, such as a 2 by 4, the length of the lane width, and to drag the surface 2 or 3 feet behind the spreader. The broom should be inclined slightly to prevent the bristles from gouging the pavement.

126. Rolling

Rollers should be wet to prevent the mix from sticking to them. A number of clean boards should be used at the end of the lane of sufficient length to support the roller to prevent contact with the base. The boards should be as thick as the loose depth of the pavement to be rolled or they should be ramped to meet it. The wheels of the roller should be completely clean before the roller moves from the boards to the mix. Rolling freshly laid pavement should be accomplished when the desired density can be obtained without raveling or blistering. Time periods required for rolling after pavement is laid may vary greatly, depending on the thickness of pavement and weather conditions. The following subparagraphs describe the method of rolling hot mix:

a. Techniques of Rolling. Initial rolling (breakdown rolling) should always be accomplished before the surface has cooled to avoid surface checking, which is difficult to correct. Initial rolling is usually performed with the three-wheel roller. *Rolling should be performed with the power wheel forward or nearest the finisher (fig. 34).* This will cause the mat to be tucked under the roller wheels instead of being pushed as when the tiller wheel is in front. If the mat as a whole is too cold, proper density cannot be secured. Ordinarily, the roller should follow the spreader closely. If the mix is too hot, the surface may blister as a result of the water boiling off the wheels and the mix then sticking to the dry wheels. Where this occurs, the mix should be loosened with rakes to a depth of about ½ inch over an area somewhat larger than the blister, and raked smooth. For best results, rolling techniques should be varied with mix characteristics and other conditions. Hot mix is a sensitive material, and few mixes react to the rollers in identical fashion. The rear wheels of the three-wheel roller supply most of the compaction, although when some mixes are very hot, they will not take the rear wheels without undue displacement and sometimes checking. Siliceous aggregates that have poor affinity for asphalt sometimes show this tendency and it may be necessary to hold the roller farther back to permit the mix immediately back of the spreader to cool slightly. If the temperature is suitable for rolling and the three-wheel roller unduly checks or shoves the pavement, the mix may require adjustment. Satisfactory mixes should not check or shove under proper rolling with a three-wheel roller. The density in the field must always meet requirements. Variations may occur in the surface from the forward and backward movements of the roller.

Note. Overpriming will often cause rolling difficulties similar in appearance to those caused by a very hot mix.

b. Correction of Uneven Surfaces. The completed pavement should conform to requirements for surface smoothness. The surface should be tested with a straightedge after the first roller pass when the mix is still hot and the surface may be loosened. When a deficiency is located, sufficient checks should be made in the area immediately surrounding it to ascertain whether it is caused by a depression of high spot. To correct a depression, the material should be loosened with rakes to a depth of approximately ½ inch and fresh hot material should be distributed by hand and raked smooth. If the irregularity is in the form of a high spot, the mix should be loosened with rakes to a depth somewhat greater than final desired grade, the excess material removed and the surface raked smooth. Straightedge tests should be made after final rolling to check conformity with surface smoothness criteria.

c. Uniformity of Rolling. The surface must be rolled as uniformly as possible to obtain a pavement that is true to grade and compacted to a uniform density. Heavier rolling at the edges of the lane than in the center will produce a crowned lane. Insufficient rolling is far more objectionable than extra rolling. When an outside lane is rolled, uniform coverage with the rear wheels may not be possible because the roller cannot be operated with one of the wheels off the pavement. The rear wheel coverage can be completed when the adjoining lane is placed. When a fresh lane is rolled adjoining a completed lane with the joint either hot or cold, the three-wheel roller should be eased from the old lane onto the new and the first pass made with one rear wheel centered on the joint and the other rear wheel on the completed pavement. Rolling should continue across the fresh lane, progressing by the width of the rear wheel less a reasonable lap to avoid leaving a ridge. With this rolling system, the half lane near the old pavement receives twice as many rear-wheel passes as the other half; but if the system is followed through successive lanes, uniform coverage will be obtained. The place where reversal of direction in rolling takes place should be staggered a minimum of 5 feet. This will help eliminate any ridges formed by starting and stopping the roller.

d. Displacement. Displacement occurs when the pavement moves on the base or binder course while being rolled. This movement may be accompanied by transverse or longitudinal cracks. Displacement is the result of a very hot mix, excessive tack coat or overpriming, or too many rounded fine particles. If displacement occurs, rolling should be discontinued immediately, the cause determined, and action taken to correct the deficiency.

e. Rolling With Pneumatic-Tired Roller. Pneumatic rolling of the asphaltic concrete pavement provides a more closely knit surface by seating the larger aggregate particles better and by closing hair cracks. Pneumatic rolling should be performed while the pavement is still warm. These light rollers have little effect when pavement temperature is lower than 130° F. To obtain the desired results, the pneumatic-tired roller should work continuously during laydown.

f. Final Rolling. After the three-wheel and/or pneumatic-tired rolling, the surface should be ironed out with a three-axle tandem roller or a two-axle tandem roller, or both. Rollers must not be left stationary on the fresh pavement as marks will be made that are almost impossible to remove.

127. Pavement Imperfections and Probable Causes

Hot-plant-mix pavement imperfections and probable causes are shown in figure 59.

128. Density Tests

Density test samples should be taken and tests performed as often as conditions require, but at least once for every 400 tons of mix placed. To obtain a satisfactory specimen, the samples should be taken early in the morning when the pavement is cool. Any additional rolling required as a result of the tests should be done during the heat of the day.

a. Source of Test Sample. The sample for testing may be taken from any portion of the lane, provided the area is typical of placing and rolling conditions. Cores, 4 inches in diameter, have proved satisfactory for density samples. Core samples are relatively small and errors are multiplied accordingly; therefore, care is necessary in weighing the samples.

b. Removing Sample. A coring machine or a concrete saw may be used for cutting out the samples. Chopped or jack hammered samples should be avoided if possible as these are likely to develop cracks or other disturbances which would lead to erroneous results. Samples from a binder or surface course should be cut out approximately 1 foot square, completely through the thickness of the pavement, and removed carefully to avoid damage. In hot weather it may be necessary to chill the area with ice for 15 to 30 minutes before cutting out the sample. The sides of the hole should be vertical or dressed to vertical after the specimen is removed. The edges and bottom of the hole should be painted in accordance with instructions for a trimmed joint described in paragraph 132*b*, and filled with fresh hot mix, rolled and checked for straightedge requirements.

c. Sample Identification. The specimen should be sent to the plant laboratory with proper identification. A simple system of numbering may be used, including designation as to whether the sample is from the binder or surface course, date placed, date sampled, structure (such as runway or taxiway), lane number, with lane centerline offset, and station number.

d. Frequency of Tests. As a general check, at least one test for density (TM 5-530) should be performed once a day on a chunk density sample.

e. Selection of Test Spot. When density samples are taken from a surface course placed on a binder course, it is practically impossible to remove the specimen from the tacked binder course surface. To assist in removing samples of the surface course from the binder course, the spot for the test should be selected in advance of laying the surface course and a piece of wrapping paper about 18 inches square placed on the spot selected. On the side of the lane least subject to construction traffic, two nails should be driven in the base or pavement a convenient distance apart and equidistant from the center of the paper so that the center of the paper may be readily located after the surface course is laid. The roller should not treat the mix placed over the paper differently from the remainder of the pavement. The area of pavement over the

PROBABLE CAUSES OF IMPERFECTIONS IN FI PAVEMENTS																					
EXCESSIVE PRIMECOAT	IMPROPER PROPORTIONING	UNSATISFACTORY BATCHES IN LOAD	POOR HANDWORK BEHIND SPREADER	EXCESSIVE SEGREGATION IN LAYING	INADEQUATE ROLLING	POOR SPREADER OPERATION	MIXTURE TOO HOT OR BURNED	MIXTURE TOO COLD	ROLLING MIXTURE WHEN TOO HOT	ROLLING MIXTURE WHEN TOO COLD	POORLY GRADED MIXTURE	UNSTABLE BASECOURSE	FAULTY ALLOWANCE FOR COMPACTION	ROLLER STANDING ON HOT PAVEMENT	MIXTURE TOO COARSE	LACK OF BITUMEN IN MIXTURE	EXCESS OF BITUMEN IN MIXTURE	INADEQUATE CROSS ROLLING	NOT CUT BACK TO UNIFORM THICKNESS	EXCESSIVE MOISTURE IN MIXTURE	TYPES OF PAVEMENT IMPERFECTIONS THAT MAY BE ENCOUNTERED IN LAYING HOT PLANT MIX PAVING MIXTURES
☒		☒															☒				BLEEDING
							☒									☒				☒	BROWN, DEAD APPEARANCE
	☒	☒		☒							☒				☒						POOR SURFACE TEXTURE
	☒	☒	☒	☒	☒	☒		☒	☒	☒		☒		☒				☒			ROUGH UNEVEN SURFACE
			☒					☒					☒						☒		UNEVEN LATERAL JOINTS
			☒			☒		☒		☒			☒						☒		UNEVEN LONGITUDINAL JOINTS
					☒					☒								☒			ROLLER MARKS
	☒	☒					☒	☒	☒		☒						☒			☒	PUSHING
			☒			☒		☒	☒					☒							WAVES
	☒	☒		☒				☒		☒	☒				☒	☒					CRACKING
	☒	☒	☒	☒		☒		☒							☒						HONEYCOMB
			☒		☒	☒			☒			☒						☒			DISTORTION
		☒				☒		☒								☒					TEARING OF SURFACE DURING LAYING
	☒	☒															☒				RICH OR FAT SPOTS

Figure 59. Hot-mix pavement imperfections and probable causes.

paper is small, and practice has demonstrated that specimen density secured by this method is approximately equivalent to the density in the surrounding pavement. Frames or separators around the proposed sample should not be used.

129. Correction of Low Density

When the density tests on samples from the completed pavement show that the minimum specified density has not been obtained, the deficiency should be corrected by additional rolling or the pavement removed and replaced to meet the minimum specified density. Where constant difficulty is being experienced in meeting the specified density, a thorough check should be made of the job-mix formula. A slight change in the gradation or in the bitumen content may improve the density. Density of the pavement should be determined as often as necessary to check conformance to specifications. If density is within 0.5 percent of the minimum specified, the pavement should be rerolled thoroughly with the three-wheel roller, securing complete rear-wheel coverage, and followed with the tandem roller. Because rolling is more effective on a warm pavement than on a cold pavement, it is desirable to reroll during the heat of the day. After rerolling, the density should be rechecked. If density is below the minimum density specified, the pavement should be rerolled thoroughly and the density checked by another test. So that additional specimens may be removed intact for density check tests, it is advisable to include one or two extra papers between the binder and surface courses at other locations in addition to the originally planned density test papers. If necessary, in view of the new density results, the pavement should be again rerolled. If the density is more than 1.0 percent below the minimum specified, the pavement should be rerolled and the density checked. Beneficial increases in density may be obtained by rolling the pavement while it is warm from the sun with a heavy pneumatic roller with the tires inflated to 90 psi. Turns should be on a radius large enough to prevent scuffing. If the aggregate gradation is within the typical specification band and a mix conforming to mix-design criteria, binder-course density should be achieved readily and surface-course density without a great deal of difficulty when the weather is warm to hot. When the weather is very cold, difficulty may be experienced. A thorough check of the job mix should be made if the density consistently falls below that specified.

130. Spacing Longitudinal Joints

When both binder and surface courses are [illegible] be laid, the joints must be offset, by at least 1 foot. To avoid unsatisfactory spacing of joints, a general paving lane plan should be worked out. Asphalt finishers usually operate with greater efficiency when laying standard 10-foot lanes; however, they may be adjusted for wider lanes or narrower lanes. Because the surface course is usually more critical than the binder course, it should be laid in standard 10-foot lanes. Variation in width of the lane is usually limited to the binder course. The example given below illustrates one of many methods of placing lanes on the binder and surface courses to assure that the joint is offset by at least 2 feet. Assuming a center-crowned runway 150 feet wide:

Binder Course: The first lane of the binder course is to be placed to a 10-foot width with one edge along the centerline of the runway. The adjoining four lanes are to be placed to 10-foot widths, leaving 25 feet between the outer edge of the fifth lane and the runway edge. The sixth lane is to be placed to a 9-foot width, and the seventh and eighth lanes to 8-foot widths. This procedure is repeated on the oth[illegible] half of the runway.

Surface Course: The first lane of the surface course is to be centered on the centerline of the runway, and the screeds adjusted to provide the desired crown and grade. The adjoining lanes are to be continued in even 10-foot widths to the runway edges.

131. Hot and Cold Longitudinal Joints

Joints may be laid and rolled either hot or cold. Choice of method should be based on experience of personnel as well as other factors. When the adjacent lane is placed while the mix in the preceding lane is still hot, the joint is called a hot joint. When the mix in the preceding lane has cooled before the adjacent lane is placed, the joint is called a cold joint. In general, hot joints are more satisfactory than cold joints and require less work. However, the only way that hot joints can be made is by making very short runs which result in a large number of transverse joints. Because smooth transverse joints are difficult to make, actual operations consist of a combination of both hot and cold joints. In either a hot or cold joint, particular care should be given to obtaining a vert cal face free of excess loose coarse material. This l eliminate voids or depressions in the joint when is rolled.

132. Construction of Longitudinal Joints

a. Hot Joints. Hot joints are laid with a short paving run on one lane with a return to the starting point by the finisher and paving the adjacent lane in the same direction. The first lane should be rolled to within 6 inches of the edge and the fresh mix placed against the hot unrolled material. The length of the run varies with rolling characteristics of the mix, temperature of the mix, and particularly with weather conditions. The length of the initial lane should be short enough so that the joint will be hot, but the run should not be so short that the operation is merely a series of stops and starts. In general, the length of the run should not exceed the distance required to maintain the mix in the unrolled edge of the initial lane at a minimum of 175° F. The finisher should be butted tight to the old lane. Rakes are used to smooth off the joint, including any ridge of loose mix in the first lane pushed up by the finisher (fig. 60). The surface should be dressed to a uniform texture. Advantages of a hot joint are that density and uniformity are superior to a cold joint and the joint is tighter and more homogeneous if the run is short enough to maintain temperature requirements in the unrolled edge.

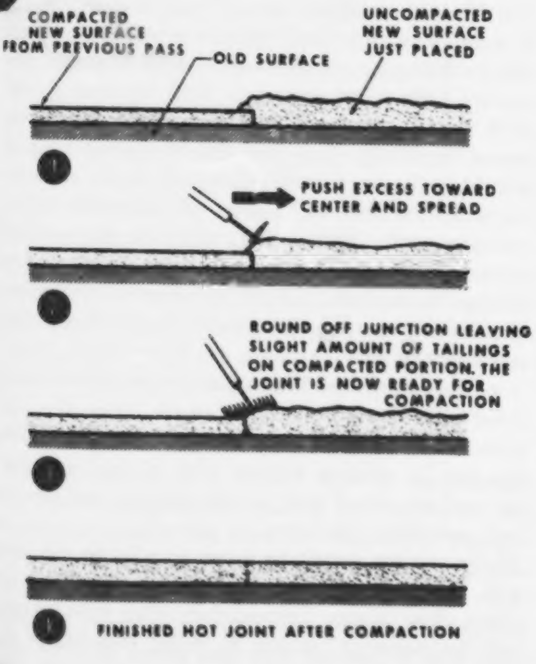

COMPACTED NEW SURFACE FROM PREVIOUS PASS
OLD SURFACE
UNCOMPACTED NEW SURFACE JUST PLACED
PUSH EXCESS TOWARD CENTER AND SPREAD
ROUND OFF JUNCTION LEAVING SLIGHT AMOUNT OF TAILINGS ON COMPACTED PORTION. THE JOINT IS NOW READY FOR COMPACTION
FINISHED HOT JOINT AFTER COMPACTION

Figure 60. Correct method of raking a joint.

b. Cold Joints. Cold joints are made when a new lane is placed next to a cold existing lane. When cold joints are to be formed, the existing lane is rolled across its entire width during the original construction. The edge is rolled with the roller overhanging the edge about 1 inch. Before the new lane is placed, the vertical edge of the existing lane should be trimmed to a vertical face so that clean aggregate faces are exposed. The trimmed joints are tacked, or painted, very lightly with an RC–70 cutback, or with an emulsion. If RC–70 cutback is not available, asphalt cement cutback with white gasoline may be used in the ratio of approximately one part asphalt cement and one part white gasoline.

Caution: ***Asphalt cement should not be cut back while it is above the flashpoint because of danger of explosion and fire.***

All loose material should be removed from the cold edge before a fresh mix is laid against it. The finisher should be as close as possible to the cold edge when placing the new lane, with the finisher shoe riding the old lane. Advantages in laying cold joints are that long continuous runs may be made and one lane can be open to limited traffic. Disadvantages are that the cold joint must be trimmed and painted and the new lane must be carefully placed to a loose thickness that will be compacted, within tolerances, to the same thickness as the lane already placed.

c. Hot and Cold Joints. A combination of hot and cold joints is generally used only when the plant breaks down or when delivery of the mix is interrupted. The method is a variation of the methods described in *a* and *b* above. A convenient length should be paved, such as 1,000 to 1,500 feet, and the adjoining lane paved in the opposite direction.

133. Alinement of Longitudinal Joints

a. Laying Initial and Succeeding Lanes. A stringline is placed to guide the finisher. The first lane is placed along the edge of the line. Succeedinig lanes are placed against the edge of the previously laid lanes rather than to a line. In airfield construction, a stringline should be placed along the outside edge to verify conformance of the pavement after the third or fourth lanes are placed. Frequently, sharp, relatively short, horizontal waves will exist in the outside edge of the third or fourth lane. When the finisher attempts to follow these waves, the waves are accentuated in the next lane. In addition to being unsightly, the wavy condition is conductive to ragged, nonuniform joints of variable density. Before this condition becomes exaggerated, a new stringline should be laid along the outside edge, parallel to the first stringline as a guide for the next lane. The stringline may be laid either to cut through sharp protruding areas, which should be cut back to line, and minor recesses filled in by hand when the next lane is paved, or it may be laid at or near the ends of the protruding areas, leaving only minor portions to be cut back to line and larger recesses to be filled.

b. Placing Pavement to Second Stringline. Gaps or recesses remaining between the previous lane and the next lane should be handfilled and the surface raked smooth. Because hand-placed material will have a lower density than the material placed by the finisher, these areas must be dressed slightly high. Such areas should be closely tested with a straightedge after the first roller pass. A new stringline should be used before the alinement necessitates extensive handfilling.

134. Transverse Joints

a. Arrangement. A transverse joint is formed in the pavement at the termination of a lane. Although it is usually advisable to carry a continuous transverse joint throughout as many lanes as practicable, joints may be staggered.

b. Terminating a Lane. When the placement of mix in a lane is discontinued, the transverse joint should be rolled to a feathered edge. The feathered section, which may extend several feet, should be cut back to full depth of the pavement. If the portion to be removed is placed directly on the primed base, some of the base material will be torn out when the edge is removed and the pockets in the base will have to be patched back to grade or other corrective measures taken to avoid extra depth of the pavement along the edge of the joint. One preventive measure is to place a strip of heavy wrapping paper, 30 to 36 inches wide, so that one edge is along the joint line and the paper extends beyond the joint line. The finisher should be run to the edge of the paper. When the edge of the joint has been rolled, the pavement can be cut back to the joint and removed without disturbing the base. This procedure may be modified when a joint is formed because of insufficient hot mix from plant breakdowns or because of other reasons. When the mix has been completely run out of the finish[illegible] depth measurements and straightedge tests should be made to determine the dividing line between the satisfactory mix across the entire width of the lane and the unsatisfactory mix. The dividing line should be marked with a stringline, perpendicular to the centerline. The unsatisfactory mix should be shoveled out down to the base, leaving a vertical edge across the line. Heavy wrapping paper, 30 by 36 inches wide, somewhat longer than the width of the lane, should be placed over the base flush with the trimmed edge. The mix should be replaced on top of the paper, raked smooth, and rolled out. When operations are started again, the mix and the paper may be stripped from the base.

c. Starting From the Joint. Regardless of the method of terminating a lane, the pavement should be cut back to a vertical edge to full depth and neat line, and the joint painted. The finisher should be moved back until the leading edge of the screed is 12 to 18 inches behind the joint so that a small amount of the mix will be placed on the old pavement. This material should be pushed up to the joint with the backs of the rakes and the fresh section raked smooth so that the mix is uniform in texture and of proper depth.

d. Rolling a Single Lane Transverse Joint. O[illegible] a single lane, the joint should be rolled once with the tandem roller and checked with the straightedge. If the new section is flush or nearly flush with the old pavement, the new section will be too low after rolling. To adjust the depth, the material should be loosened with rakes to a depth of about ½ inch, the desired amount of material added, raked smooth, and rolled with the three-wheel roller. If the new lane is too high after tandem rolling, the material should be loosened with rakes, the desired amount of material removed, and the pavement rolled.

e. Rolling Other Than Single Lane Transverse Joints. On lanes other than single lanes, the first pass should be made parallel to the centerline from the new to existing surface with a tandem roller, the surface tested with a straightedge, and low or high condition corrected as described in *d* above. The pavement should be rolled parallel to the joint with the tandem roller centered on the joint for about three passes. Immediately after tandem rolling, the pavement should be rolled parallel to the joint with the three-wheel roller, with one rear wheel centered on the joint, and the other re[illegible] wheel on the old pavement. Transverse rolling hould not extend beyond 6 or 8 inches from the utside edge, which will be rolled longitudinally.

f. Pavement Ends. Pavement ends are flattened by the movement of trucks and other equipment. Six to eight inches of additional length should be added to the length of the pavement. At the end of the job, the pavement should be cut back to a neat line in conformance with specifications, and backfilled.

Section VIII. SPECIAL MIXES

135. Types of Special Mixes

Sand-asphalt and sand-tar mixes, sheet asphalt, stone-filled sheet asphalt, and rock asphalt are special types of mixes that may be used for binder and surface courses. Each type of mix is discussed below.

136. Sand-Asphalt and Sand-Tar Mixes

In regions where sand of acceptable quality is the only local aggregate available, such as in coastal areas, sand mixes may be used for an economical surface course that will meet minimum requirements. Sand mixes may be used for paving roads and streets where light fast-moving traffic is anticipated. Sand mixes may also be used for surface and binder courses in pavements designed for low-pressure tires and in nontraffic areas. They are not suitable for surface and binder courses for airfield avements designed for high-pressure tires nor for ndustrial-type pavements designed for solid rubber tires or steel wheels. The sand should be sufficiently well graded to meet the specified requirements for the type of course to be laid and free from excessive amounts of foreign material. When high stability is required, gradation may be improved by selecting and blending locally available sand. Mineral filler is usually added to the sand to increase the density and stability of the mix. Asphalt cement, asphalt cutback, tar, or asphalt emulion may be used as a bitumen. Hot mix or cold-laid lant mix are produced from sand mixes in a central lant; road mixes are produced with a travel plant r the usual mixed-in-place equipment.

37. Sheet Asphalt

Sheet asphalt is a refined type of sand-asphalt avement in which the grading and quality of sand nd mineral filler are carefully controlled. The per- ntage of asphalt required, in general, is higher an the amount required for sand asphalt. Sheet phalt provides a smooth, impermeable, homogene- us surface course that may be used in thin layers n an adequate base course. It is usually constructed as a surface course over a binder course in layers 1½ to 2 inches thick. The surface may be finished to a fine, gritty, skid-resistant texture, with smooth riding qualities, high uniformity, and low-abrasive quality. Sheet asphalt is most satisfactory when subjected to the action of traffic over the entire surface. Like sand-asphalt and sand-tar mixes, sheet asphalt is suitable for roads and streets, but it is not suitable for pavements designed for high-pressure tires (airfields) nor for industrial type pavements designed for solid rubber tires or steel wheels.

138. Stone-Filled Sheet Asphalt

Stone-filled sheet asphalt usually consists of coarse aggregate passing the ⅝-inch sieve and retained on the No. 8 sieve in varying quantities not exceeding 40 percent, well-graded sand, mineral filler, and asphalt cement, prepared in the same manner as sheet asphalt. Basically, stone-filled sheet asphalt is a type of sheet asphalt with all of its general characteristics. The percentage of coarse aggregate varies proportionately when the specific gravities of the fine aggregate and of the coarse aggregate are not uniform. Stone-filled sheet asphalt is usually used as a surface course constructed in layers 1½ to 2 inches thick. Stone-filled sheet asphalt is widely used for surfacing roads and streets; like sheet asphalt, it is unsuitable for use in industrial areas and for high-type airfields.

139. Rock Asphalt

a. Composition and Use. Rock-asphalt pavement is composed of crushed, natural, asphalt impregnated stone, such as limestone, sandstone, or a combination of these, used alone or mixed with additional asphalt. Rock-asphalt pavement is laid either hot or cold, depending upon the type of rock asphalt, in the same manner as asphaltic concrete. Rock asphalt is only used in surface courses. The natural rock-asphalt deposits that produce paving material commercially are located in Kentucky, Alabama, Texas, New Mexico, Oklahoma, and Utah.

The nature of the material found in the different pits varies in both the aggregate and in the asphalt. Some of the natural materials in the same pit vary in asphalt content and are blended to produce a uniform mix. Materials in some other pits are low in asphalt content and these mixes should be enriched with additional asphalt.

b. Types. The two general types of rock asphalt are blended rock asphalt and fluxed rock asphalt. Blended rock asphalt is prepared by blending crushed impregnated limestone or sandstone, or a combination of the two, in proper proportions to produce a mix properly graded and of a specified asphalt content. Grading of the mix is often subordinated to balancing of the asphalt content. Fluxed rock asphalt is prepared by blending crushed impregnated limestone or sandstone, or a combination of the two, with asphalt cement and/or cutter stock in a pug-mill, producing a mix properly graded and with a specified asphalt content. The enriching of the natural rock asphalt is necessary if the material contains insufficient asphalt in its natural state to produce a satisfactory pavement. Hot-plant mixes are sometimes produced by heating crushed limestone impregnated with relatively hard asphalt, alone or with added sand, and mixing with additional asphalt cement in the central plant. This type of mix is essentially a sand asphalt. Rock asphalt is a satisfactory surfacing material for roads and streets subjected to all-over traffic, but has the same limitations as sand asphalt for use in airfield pavements and industrial areas.

CHAPTER 7

FIELD MANUFACTURE OF ASPHALT CUTBACKS

140. Introduction

Various types and grades of asphalt cutbacks can be manufactured in the field with standard equipment, and thinner cutbacks can be produced from the more viscous grades. Field manufacture of SC and MC, however, is more practicable than field manufacture of RC because of the rapid evaporation of gasoline from RC and because there is greater danger of fire or explosion from the gasoline.

141. Equipment and Production Rate

Equipment used for field manufacture of asphalt cutback is listed in table IX. Rate of production is usually controlled by the speed with which asphalt cement can be emptied from the drums and heated in the asphalt kettles to suitable temperatures for pumping. Production rate for the 750-gallon kettle is about 250 gallons per hour; for the 165-gallon kettle, about 40 gallons per hour. Suggested arrangements of equipment for use of 750-gallon kettle and the 165-gallon kettle are shown in figures 61 and 62, respectively. For small-scale production, the truck- or trailer-mounted distributor, or the 1,500-gallon trailer-mounted asphalt tank with steam coils, can be used instead of the 4,000-gallon mixing and storage tanks. Piping and pumping should be arranged to fit each particular installation. All equipment used in the field manufacture of asphalt cutbacks is discussed in chapter 5.

142. Safety

a. Listed below are several safety precautions that must be exercised while heating bitumens. These precautions should be reviewed prior to daily operations.

(1) Keep foam-type fire extinguishing equipment handy at all times.

(2) Maintain kettles and distributors in a level position prior to heating.

(3) Do not heat bitumens near buildings or inflammable materials.

Table IX. Equipment Used for Field Manufacture of Asphalt Cutbacks

Equipment	Function
Kettle, heating, bitumen skid-mounted, w/gasoline-powered pumps, 750-gallon capacity.	The 750-gallon kettle is used to heat bitumen for the field manufacture of asphalt cutback.
Kettle, heating, bitumen, gasoline-driven, trailer-mounted, 165-gallon capacity.	The 165-gallon kettle is used to heat small quantities of bitumen.
Pump, asphalt	One asphalt pump is a portable pumping unit for transferring bituminous material from heating facilities to storage tanks and another is used for transferring the cutterstock to the mixing tank. A third pump might be required for circulating cutback in heated storage tanks to obtain even temperatures when high viscosity materials are used.
Piping equipment, asphalt plant, 80–200-TPH	The piping equipment is used for connecting the 4,000-gallon tanks in series.
Tank, asphalt storage	The asphalt storage tank is used to store bitumen.
Tank, steel, gasoline and oil, two-compartment, skid-mounted, 750-gallon capacity.	The steel tank is used to hold cutterstock.
Heater, bitumen; gasoline-engine-powered, three-car heating capacity.	The bitumen heater is used to generate steam for heating stored asphalt in 4,000-gallon tanks or railroad cars.
Distributor, water, truck-mounted	The water distributor is used for water supply.

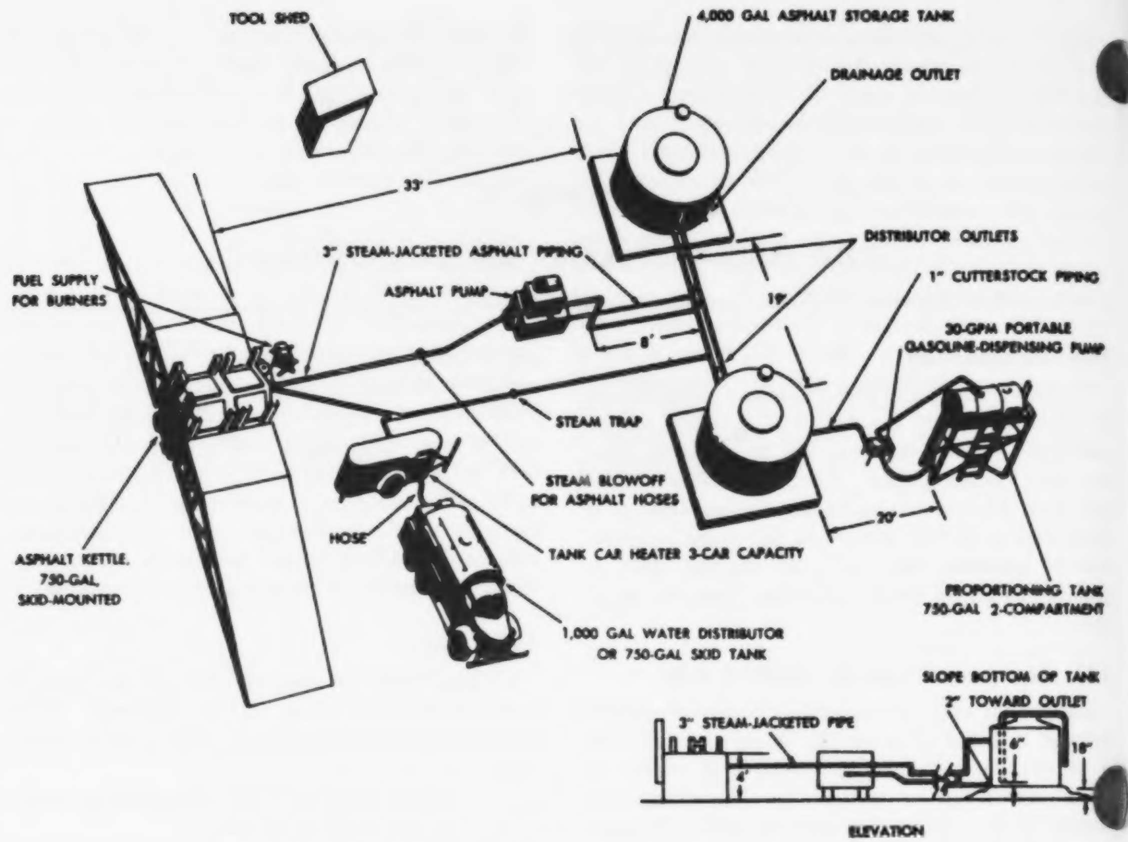

TOOL SHED
4,000 GAL ASPHALT STORAGE TANK
DRAINAGE OUTLET
33'
DISTRIBUTOR OUTLETS
3" STEAM-JACKETED ASPHALT PIPING
1" CUTTERSTOCK PIPING
FUEL SUPPLY FOR BURNERS
ASPHALT PUMP
19'
30-GPM PORTABLE GASOLINE-DISPENSING PUMP
8'
STEAM TRAP
STEAM BLOWOFF FOR ASPHALT HOSES
20'
HOSE
TANK CAR HEATER 3-CAR CAPACITY
ASPHALT KETTLE, 750-GAL, SKID-MOUNTED
PROPORTIONING TANK 750-GAL 2-COMPARTMENT
1,000 GAL WATER DISTRIBUTOR OR 750-GAL SKID TANK
SLOPE BOTTOM OF TANK 2" TOWARD OUTLET
3" STEAM-JACKETED PIPE
6"
18"
4'
ELEVATION

Figure 61. Manufacture of asphalt cutback using the 750-gallon kettle.

(4) Control ventilation of kettles and distributors to prevent escape of inflammable vapors near flames or electrical equipment.

(5) Stay to the windward side of equipment as much as possible to avoid excessive exposure to fumes.

(6) Reduce heat whenever foaming might cause overflow.

(7) Extinguish burners after bitumen has reached the average temperature given in table X.

(8) Extinguish burners and evacuate personnel if a dense yellow vapor is observed rising from a kettle or distributor. (This indicates overheating to the extent that a spark could cause explosion.)

(9) Extinguish burners before spraying a bitumen from a distributor.

(10) Do not smoke within 50 feet of any equipment at any time. Designate a smoking area at least 100 feet upwind of the equipment during heating operations.

(11) Examine all hoisting equipment daily.

(12) Do not fill buckets or containers to the top that are to be hoisted.

(13) Do not allow the asphalt level to fall below the firetubes while the burners are in operation.

(14) Close valves leading to the kettle vat during clean out operations to keep solvent spray away from burner tubes.

(15) Wear long-sleeve shirts, cuffless pants, fireproof gloves, heavy soled boots, and either a steel combat helmet or civilian safety hat. If hot bitumen should be accidentally spilled on a worker, the protection given by this type of clothing will greatly reduce the injury.

b. During actual operations, personnel often become so occupied with their particular job that they

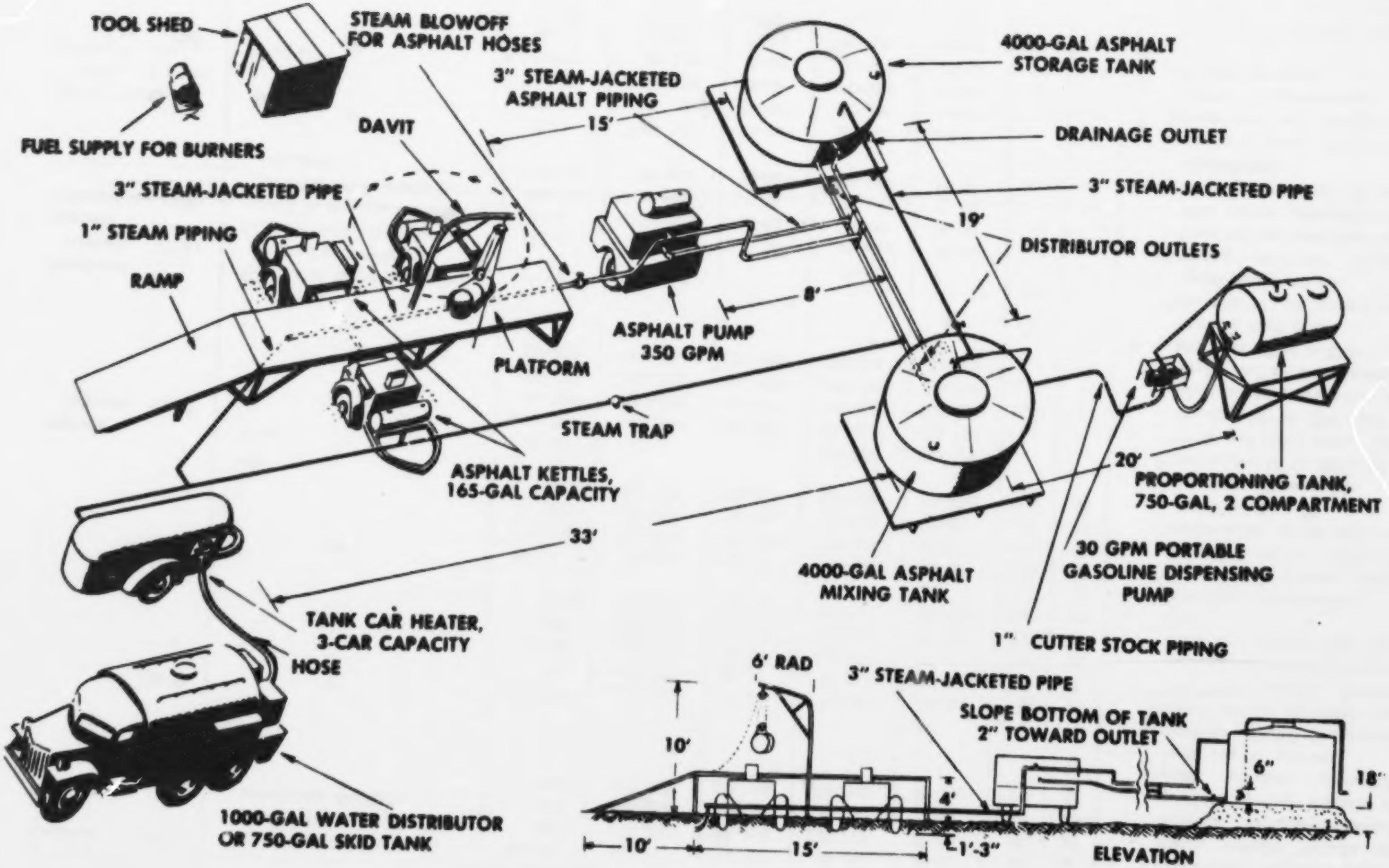

TOOL SHED
STEAM BLOWOFF FOR ASPHALT HOSES
FUEL SUPPLY FOR BURNERS
3" STEAM-JACKETED ASPHALT PIPING
15'
DAVIT
3" STEAM-JACKETED PIPE
1" STEAM PIPING
RAMP
PLATFORM
ASPHALT PUMP 350 GPM
8'
STEAM TRAP
ASPHALT KETTLES, 165-GAL CAPACITY
33'
TANK CAR HEATER, 3-CAR CAPACITY
HOSE
1000-GAL WATER DISTRIBUTOR OR 750-GAL SKID TANK
4000-GAL ASPHALT STORAGE TANK
DRAINAGE OUTLET
3" STEAM-JACKETED PIPE
19'
DISTRIBUTOR OUTLETS
20'
PROPORTIONING TANK, 750-GAL, 2 COMPARTMENT
4000-GAL ASPHALT MIXING TANK
30 GPM PORTABLE GASOLINE DISPENSING PUMP
1" CUTTER STOCK PIPING
6' RAD
3" STEAM-JACKETED PIPE
SLOPE BOTTOM OF TANK 2" TOWARD OUTLET
10'
4'
6"
18"
10'
15'
1'-3"
ELEVATION

Figure 62. Manufacture of asphalt cutback using 165-gallon kettles.

Table X. Characteristics of Bitumens

Material	Form	Grade designation	Temperature of application ranges: Spraying [1] °F.	Spraying [1] °C.	Mixing °F.	Mixing °C.	Flash point (min) °F.	Flash point (min) °C.	Remarks
Cutback (RC)	Liquid—asphalt residues fluxed with a violatile petroleum distillate.	RS–70	105–175[2]	41–79[2]	95–135	35–57	80	27	Rapid-curing cutbacks contain highly volatile Naptha cutterstock. Naphtha evaporates quickly leaving asphalt cement bitumen permitting early use of surface. ***Caution: Highly flammable.***
		–250	145–220[2]	63–104	135–175	57–79	80	27	
		–800	180–255[2]	82–124[2]	170–210	77–99	80	27	
		–3000	215–290[2]	102–143[2]	200–240	93–116	80	27	
(MC)	do	MC–30	70–140	21–60	55–95	13–35	100	37	Medium-curing cutbacks contain less volatile kerosene cutterstock. Kerosene evaporates less rapidly than Naptha. ***Caution: Flammable.***
		–70	105–175	41–79	95–135	35–57	100	37	
		–250	145–220	63–104	135–175	57–79	150	65	
		–800	180–255	82–124	170–210	77–99	150	65	
		–3000	215–290	102–143	200–240	93–116	150	65	
(SC)	do	SC–70	105–175	41–79	95–135	35–57	150	65	Slow-curing cutbacks contain slightly volatile Diesel fuel cutterstock. Diesel fuel evaporates slowly. ***Caution: Flammable.***
		–250	145–220	63–104	135–175	57–79	150	65	
		–800	180–255	82–124	170–210	77–99	175	79	
		–3000	215–290	102–143	200–240	93–116	200	93	
Asphalt Cements (AC)	Solids	40–50	-------	-------	300–350	149–177	---	--	Penetrations 40 to 100 used for crack and joint fillers. Penetrations 70 to 300 used for plant mixes, penetration macadam, and surface treatment. Use test (TM 5-530) to determine flash point.
		60–70	285–350	141–177	275–325	135–163	---	--	
		85–100	285–350	141–177	275–325	135–163	---	--	
		120–150	285–350	141–177	275–325	135–163	---	--	
		200–300	260–325	127–163	200–275	93–135	---	--	
Powdered Asphalt (PA)	Hard and solid asphalts ground to powder.	--------	-------	-------	-------	-------	---	--	Used with SC to produce extra tough road surfaces.
Asphalt Emulsions (RS)	Liquids—asphalt particles held in an aqueous suspension by an emulsifying agent.	RS–1	50–140	10–60	Non-Mixing	10–60	---	--	Freezing destroys emulsion. Used for road and plant mixes with course aggregates (SS). All emulsions with "K" suffix are cationic.
		RS–2	50–140	10–60	50–140	10–60	---	--	
		RS–2K	50–140	10–60	50–140	10–60	---	--	
		RS–3K	50–140	10–60	50–140	10–60	---	--	
(MS)	do	MS–2	50–140	10–60	50–140	10–60	---	--	
		SM–K	50–140	10–60	50–140	10–60	---	--	
		CM–K	50–140	10–60	50–140	10–60	---	--	
(SS)	do	SS–1	50–140	10–60	50–140	10–60	---	--	
		SS–1h	50–140	10–60	50–140	10–60	---	--	
		SS–K	50–140	10–60	50–140	10–60	---	--	
		SS–Kh	50–140	10–60	50–140	10–60	---	--	

Road Tars (RT)	**Liquids**	RT–1	60–125	15–52	--------	--------	---	--	Priming oils. RT–4 through RT–12 not generally used.
		RT–2	60–125	16–52	--------	--------	---	--	
		RT–3	80–150	27–66	--------	--------	---	--	
Road Tar Cut-backs (RTCB)	**Liquids**	RTCB–5	60–120	16–49	--------	--------	---	--	Patching mixtures. ***Caution: Flammable.***
		RTCB–6	60–120	16–49	--------	--------	---	--	
Rock Asphalt	**Solids**	------------	--------	--------	--------	--------	---	--	Mixed and used locally where found. Cutback may be added if necessary.

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[1] Low temperature is based on a viscosity of 200 centistokes kinematic viscosity and the higher temperature is based on a 50 centistokes viscosity.

[2] RC cutbacks are seldom used for spraying.

are unaware of other operations in their vicinity. For this reason, at least one safety inspector should be designated. His sole task will be to insure that reasonable precautions are observed within his area of responsibility.

143. Procedure

a. Procedure for field manufacture of asphalt cutbacks is outlined below. Safety precautions given in the procedure must be strictly observed to avoid the danger of fire or explosion. Heating limits for asphalt cutback are given in table X.

b. Heads should be removed from asphalt drums with special axes or cutting tools and the contents of each drum inspected. Drums should be eliminated if they are contaminated with water or material that may cause foaming and fire. Care should be taken when the drums are opened to avoid serious injury caused by improper use of cutting tools.

c. The drums are heated with a hand burner to loosen the asphalt cement, as shown in figure 63. The sides of the drum should be heated first to avoid expansion at the bottom that may burst

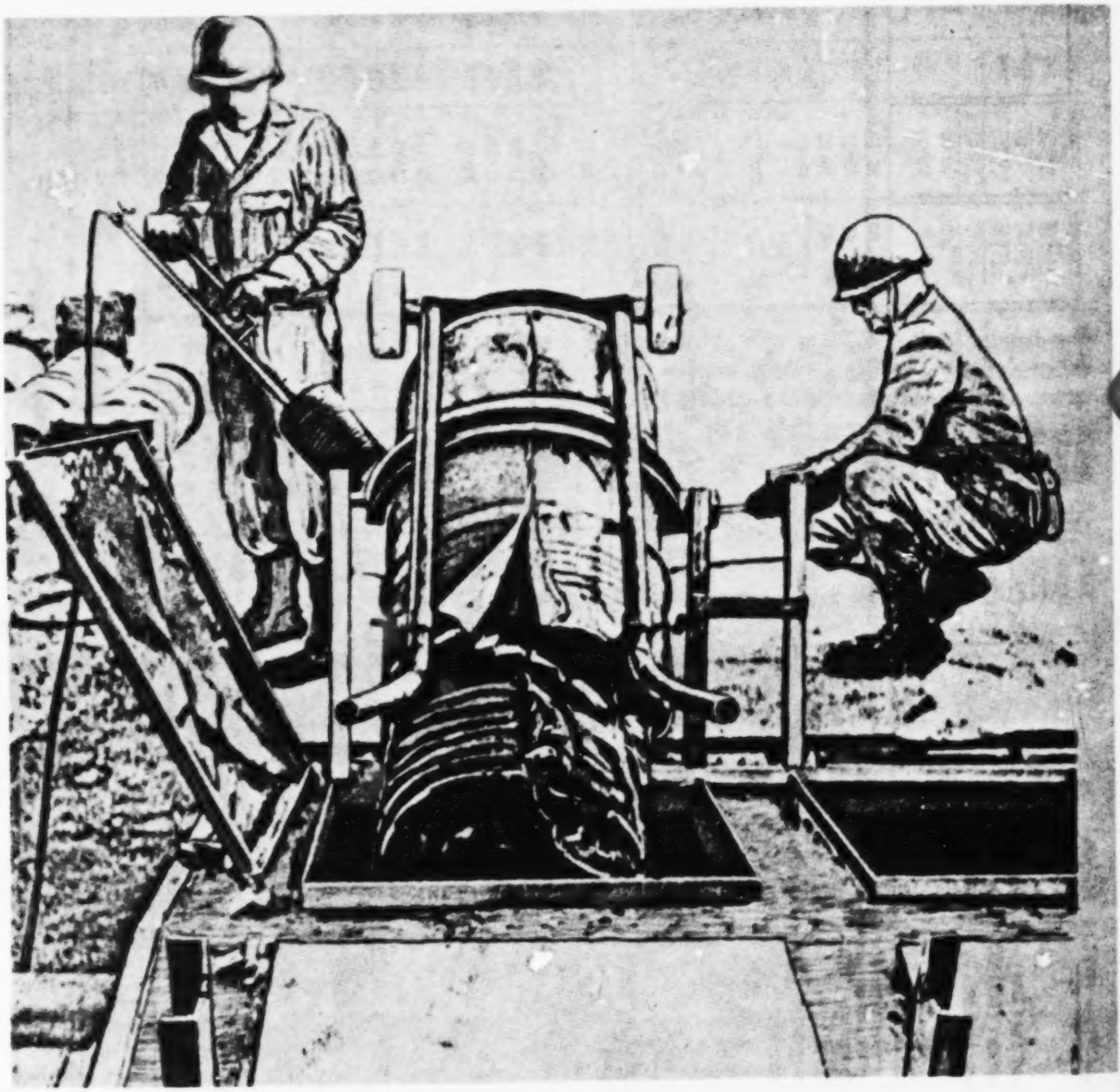


Figure 63. Dedrumming asphalt.

the drum. A dumping rack is used to place the drums over the 750-gallon kettles, or a davit for the 165-gallon kettles. The heated cores of asphalt cement will be dumped from the drums into the kettle. If the drums are completely laid open, the asphalt cement may be chopped into pieces and laid in the asphalt kettles. The asphalt cement should be heated to about 250° F. or until it is fluid enough to pump easily.

d. When the asphalt cement (or cutback) has been heated to a workable state, it should be pumped to storage. The 4,000-gallon heated tanks are usually used as storage tanks. The steam-jacketed lines between units should be used to maintain the asphalt in the pipelines at a constant temperature high enough to keep the asphalt fluid. All lines that become plugged with cold asphalt must be blown out. Steam-jacketed lines that become plugged with cold asphalt cannot be blown out. A solution is to heat the unjacketed elbows and keep steam in the jacket. If the original asphaltic material is delivered hot in tank trucks or tank cars, it may be pumped directly to the storage tanks.

e. From the heated storage tanks, about 2,000 gallons are pumped to the 4,000 gallon mixing tanks. If a distributor or trailer-mounted tank is being used for mixing small quantities, it should be pumped about half full to leave space for cutterstock and for foaming which may result when the cutterstock is added.

f. The temperature in the mixing chamber should be adjusted to a uniform temperature between 240° F. and 250° F. Pump circulation accompanied by heating, or atmospheric cooling will help regulate this temperature. As temperatures lower than 240° F., the asphalt cement will not be fluid enough to pump easily or to mix readily with the cutterstock. At higher temperatures, much of the cutterstock will be lost in gaseous form, and a serious fire hazard will exist.

g. When the original material in the mixing tank has been adjusted to the specified temperature of 240° F. to 250° F., circulation should be stopped and the quantity of material in the tank estimated. The required amount of cutterstock to add to the mixing tank should then be determined and the desired quantity pumped into the tank.

h. For best mixing, the cutterstock should be introduced near the intake pipe leading to the circulation pump. Mixing is accomplished by pumping the heated original material and the cutterstock through a closed system in the mixing tank. The openings in the tank should be covered with wet burlap or canvas while blending cutbacks, and fire-fighting facilities should be ready for use at all times. When manufacturing cutbacks from asphalt cement, pumping should start as soon as the asphalt cement if fluid enough to pump without damaging or placing a strain on the trailer-mounted asphalt pump. Temperatures should be maintained as low as possible and should not exceed 250° F. (120° C.) because of the fire hazard.

i. After mixing, usually about 30 minutes, the newly manufactured asphalt cutback should be pumped to final storage.

144. Material Requirements

a. Asphalt Cement and Cutterstock. The composition of asphalt cutbacks may be obtained from table XI. The example given below illustrates the method of calculating the combined quantities of asphalt cement and cutterstock needed for a specific type and grade of asphalt cutback.

Example: Calculate the quantity, in gallons, of asphalt cement and diesel oil that must be combined to produce 750 gallons of SC–800.

Solution: Composition of SC–800 is given in table XI. SC–800 is composed of 70 percent soft asphalt cement with preferred penetration of 200 to 300, and 30 percent of diesel oil by volume.

0.70×750 gal $= 525$ gal asphalt cement

0.30×750 gal $= 225$ gal diesel oil

b. Thinning Asphalt Cutback. Procedure for determining the proportion of cutterstock to be added to an asphalt cutback to produce a lower (thinner) grade is outlined below. Using the data in table XI, the following formula is applicable:

$$X = \frac{100\ (a-b)}{(100-b)} \quad (7\text{–}1)$$

where X = percent of cutterstock to be added to the cutback to be thinned

a = percent of cutterstock in desired cutback of lower grade

b = percent of cutterstock in cutback to be thinned

Example: Calculate the amount of kerosene and MC–800 cutback that must be combined to produce 1,000 gallons of MC–70 cutback.

Table XI. Approximate Composition of Asphalt Cutbacks

Asphalt Cutback		Asphalt Cement			Percent cutterstock by volume		
		Penetration Grade					
Type	Grade	Limits	Preferred	Percent of total volume	Gasoline or naphtha	Kerosene or jet fuel [2]	Fuel or diesel oil or similar material
Rapid Curing (RC)	70	60–150	85–100	65	35		
	250			75	25		
	800			83	17		
	3000			87	13		
Medium Curing (MC)	30	85–200	120–150	54		46	
	70			64		36	
	250			74		26	
	800			82		18	
	3000			86		14	
Slow Curing (SC)[1]	70	120–300	200–300	50			50
	250			60			40
	800			70			30
	3000			80			20

[1] Percentages of cutterstock contained in the different grades of slow-curing oils may vary with the type of cutterstock or the method of manufacture.
[2] Jet fuel should be used as a field expedient for kerosene when the latter is not available.

Solution: Using the formula:

$$X = \frac{100\ (a-b)}{(100-b)}$$ and the data in table XI.

a = 35, or the percent of cutterstock (kerosene) in MC–70, the cutback to be manufactured

b = 18, or the percentage of cutterstock (kerosene) in MC–800, the cutback to be thinned

$$X = \frac{100\ (35-18)}{(100-18)}$$

= 20.7 percent kerosene needed to produce MC–70.

100 − 20.7 = 79.3 percent MC–800 will be used.

To produce 1,000 gallons of MC–70:

1,000 × 0.207 = 207 gallons of kerosene will be combined with

1,000 × 0.793 = 793 gallons of MC–800

c. *Yield.* The following example illustrates the method of calculating yield:

Example: Materials available in the field for bituminous construction include 1,000 gallons of 120 to 150 penetration asphalt cement, 750 gallons of MC–3,000, and 1,750 gallons of kerosene. It is necessary to produce an MC–30 for use as a prime material.

(1) The number of gallons of MC–30 should be determined that can be produced by combining all the asphalt cement with kerosene.

(2) The number of gallons of MC–30 should be determined that can be produced by combining the 750 gallons of MC–3000 with kerosene.

(3) The quantity of MC–30 in gallons that will be produced should then be determined.

Solution:

(1) It is first necessary to determine the percentages of asphalt cement and kerosene in an MC–30. This can be found by referring to table XI.

MC-30 = 54 percent asphalt and cement
and 46 percent kerosene

If 1,000 gallons of 120 to 150 penetration asphalt cement represent 54 percent of the MC-30 to be produced, then the number of gallons of kerosene to be added to the asphalt cement can be determined by the use of this simple proportion:

$$\frac{\text{percent of asphalt}}{1{,}000\ \text{gal}} = \frac{\text{percent kerosene}}{X\ \text{gal}}$$

$$\text{or}\ \frac{54}{1000} = \frac{46}{X}$$

$$X = \frac{46 \times 1{,}000}{55} = 836\ \text{gal}$$

The number of gallons of MC–30 produced by adding 1,000 gallons of asphalt cement and 836 gallons of kerosene is then:

1,000 + 836 = 1836 gal MC–30

(2) To determine the percentages of kerosene to be added to MC–3000 to produce MC–30, the formula given below is used:

$$X = \frac{100\ (a-b)}{(100-b)}$$

Where X = percent kerosene to be added to MC–3000

a = percent kerosene in MC–30 = 46

b = percent kerosene in MC–3000 = 14

Then $X = \frac{100\ (46-14)}{(100-14)} = \frac{3200}{86}$

= 37.2 percent kerosene to be added to MC–3000 to produce MC–30

Then $\frac{37.2}{750} = \frac{\text{percent kerosene}}{X\ \text{gal}}$

(3) To determine the number of gallons of MC–30 that can be produced by combining the 750 gallons of MC–3000 with kerosene:

X = gal of kerosene required to 750 gal of MC–3000

X = 100 − 37.2 = 62.8 percent MC–3000

$$\frac{62.8}{750} = \frac{37.2}{X}$$

$$X = \frac{750 \times 37.2}{62.8}$$

X = 444 gal kerosene

Checking the availability of kerosene:

Total available = 1750 gal
Used previous = *836 gal*
Now available = 914 gal

Since 914 gallons of kerosene are available and only 444 gallons are needed, enough kerosene is available to thin all of the MC–3000. Adding the 750 gallons of MC–3000 to the 444 required gallons of kerosene:

750 + 444 = 1194 gal MC–30

The total number of gallons of MC–30 is:

1836 + 1194 = *3,030 gal MC–30*

CHAPTER 8

MATERIALS ESTIMATES

145. Introduction

Bituminous materials and aggregate are combined in various proportions to obtain the most satisfactory surface. Accurate estimates are extremely important to avoid an inadequate supply with consequent delay in production or to avoid oversupply and waste of materials. Estimates should be based on the sequence of operations and the materials required for each construction step. Materials should arrive at the paving site shortly before they are actually needed. Because later adjustments may be necessary, only the minimum amount of materials required for full-scale operation should be kept on hand. The formulas in the following paragraphs have been set up to take into consideration the shrinkage that takes place when the bitumen cools after barreling operations by using 40 gallons per barrel as a conversion factor. This does *not* consider the loss of bitumen in debarreling operations.

146. Requirements for a Prime Coat

To estimate the amount of bitumen required for the prime coat, the area to be treated is multiplied by the rate of application. The estimate must include sufficient bitumen for an additional width of 1 foot on each side of the surface course to be constructed on the primed base.

The formulas for a prime coat estimate are—

$$G=\frac{L\times (W+2)\times R_b\times (1.00+H_b)}{9}\text{gallons, or} \quad (8\text{–}1)$$

$$B=\frac{L\times (W+2)\times R_b\times (1.00+H_b)}{360}\text{barrels} \quad (8\text{–}2)$$

where:

G = gallons of bitumen primer.
B = barrels of bitumen primer.
L = length of treated section in feet. (Miles may be converted by multiplying by 5,280.)
W = width of treated surface in feet.
R_b = rate of application of bitumen in gallons per square yard.
H_b = Handling loss factor for bitumen.
9 = square feet per yard conversion factor.
$360=40\times 9$ or gallons per barrel and square feet per square yard conversion factor.

Example: The specifications and other data for a prime coat project are as follows:

$L=3$ miles $=3\times 5{,}280=15{,}840$ feet
$W=23$ feet
$R_b=0.3$ gal/sq yard
$H_b=0.05$ or 5 percent

Find the number of gallons of bitumen (G) necessary to do this project.

Solution: $$G=\frac{15{,}840\times (23+2)\times 0.3\times (1.00+0.05)}{9}$$

$G=13{,}860$ gallons

147. Requirements for a Tack Coat

The procedure for estimating the bitumen required for a tack coat is similar to that described for a prime coat except that the tack coat is generally applied only over the proposed width of the pavement. The formulas for a tack coat are—

$$G=\frac{L\times W\times R_b\times (1.00+H_b)}{9}\text{gallons, or} \quad (8\text{–}3)$$

$$B=\frac{L\times W\times R_b\times (1.00+H_b)}{360}\text{barrels,} \quad (8\text{–}4)$$

where:

G = gallons of bitumen.
B = barrels of bitumen.
L = length of treated section in feet.
W = width of treated section in feet.
R_b = rate of application of bitumen in gallons per square yard.
H_b = handling loss factor for bitumen.

9 = square feet per square yard conversion factor.

360 = 40 × 9 or gallons per barrel and square feet per square yard conversion factor.

Example: The specifications and other data for a tack coat project are as follows:

$L = 2.7 \text{ miles} = 2.7 \times 5{,}280 = 14{,}256 \text{ feet}$

$W = 23 \text{ feet}$

$R_b = 0.5 \text{ gal/sq yd}$

$H_b = 0.05 \text{ or } 5 \text{ percent}$

Find the number of barrels of bitumen that will be needed to do this project.

Solution:

$$B = \frac{14{,}256 \times 23 \times 0.5 \times (1.00 + 0.05)}{360}$$

$$B = 478.2, \text{ or } 478 \text{ barrels}$$

148. Requirements for a Surface Treatment

In bituminous surface treatments, the unit quantities of bitumen and aggregate can be determined by a test strip, by specifications of the job, or by an approximation of about 1 gallon of bitumen for every 100 pounds of aggregate, or 0.1 gallon of bitumen for every 10 pounds of aggregate. The weight of the aggregate, one stone in depth, required to cover 1 square yard is determined by spreading the aggregate to be used one stone in depth over a measured surface, weighing it, and computing the amount in pounds per square yard.

The formulas for a surface treatment are—

$$P = \frac{L \times W \times R_a \times (1.00 + H_a)}{9} \text{ pounds, or} \qquad (8\text{–}5)$$

$$T = \frac{L \times W \times R_a \times (1.00 + H_a)}{18{,}000} \text{ tons for the determination} \qquad (8\text{–}6)$$

of aggregate.

where:

P = weight of aggregate in pounds.

T = weight of aggregate in tons.

L = length of treated surface in feet.

W = width of treated surface in feet.

R_a = rate of application of aggregate.

H_a = handling loss factor for aggregate.

9 = square feet per square yard conversion factor.

18,000 = 2,000 × 9 or pounds per ton and square feet per square yard conversion factor.

The formulas for bitumen determination are the same as those for a tack coat. The materials for a multiple surface treatment are determined by the same method as above except that the results are multiplied by the number of treatment passes.

Example: A test strip with an area of 100 square yard was used to determine the quantities for a single surface treatment. Careful control was made of materials and handling losses were negligible. A check of materials consumption showed that 1.50 tons of aggregate and 30.0 gallons of bitumen were used. Based on previous experience an aggregate handling loss of 10 percent (0.10) and a bitumen handling loss of 5 percent (0.05) are expected. Find the tons of aggregate and barrels of bitumen necessary to make a single surface treatment on a road 23 feet wide and 10 miles long.

Solution:

(1) Aggregate

$$R_a = \frac{1.50 \text{ tons} \times 2000 \text{ lb/ton}}{100 \text{ sq yd}} = 30 \text{ lb/sq yd}$$

$$T = \frac{(10 \times 5{,}280) \times 23 \times 30\ (1.00 + 0.10)}{18{,}000}$$

$T = 2226.4$, or *2227 tons*

(2) Bitumen

$$R_b = \frac{30 \text{ gallons}}{100 \text{ sq yd}} = 0.30 \text{ gal/sq yd}$$

$$B = \frac{(10 \times 5{,}280) \times 23 \times 0.30 \times (1.00 + 0.05)}{360}$$

$B = 1062.6$, or *1063 barrels*

149. Requirements for Penetration Macadam

The procedure for determining the amount of bitumen for a penetration macadam pavement is identical to that outlined for a tack coat and for a surface treatment, that is, area × rate × handling loss. The approximate amount or rate of the bitumen is 0.75 gal/sq yd per inch of compacted thickness. *For example,* a 2-inch compacted thickness will require 2 × 0.75 or 1.5 gal/sq yd. To determine the loose volume of aggregate, the area to be paved is multiplied by the compacted thickness of the aggregate and the compaction factor, which is the ratio of the volume of loose aggregate to the volume of compacted aggregate. The compaction factor for a 4-inch loose layer of aggregate compacted to 2 inches is 2. If a 2-inch compacted thickness is desired and the compaction factor is 1.5, the loose thickness is 1.5 × 2 inches, or 3 inches. The compaction factor must be determined in the field in relation to the angularity and roughness of the aggregate, the loose thickness of the layer, and the weight of the roller. Compaction factors usually vary from about 1.2 to 1.5.

The formulas for penetration macadam are—

$$V = \frac{L \times W \times FPT \times CF \times (1.00 + H_a)}{324} \text{ loose cubic yards} \qquad (8\text{–}7)$$

where:

V = loose volume of aggregate in cubic yards.
L = length of surfaced area in feet.
W = width of surfaced area in feet.
FPT = finished pavement thickness in inches (depth of surface after all compacting operations are completed).
CF = compaction factor or ratio of loose depth to FPT.
H_a = aggregate handling loss factor.
$324 = 36 \times 9$ or inches per yard and square feet per square yard conversion factor.

The formulas for bitumen determination are the same as those used for a tack coat and those for chokestone and keystone the same as those used for multiple surface treatments.

Example: The specification and data for a penetration macadam project are as follows:

$L = 2$ miles
$W = 23$ feet
$FPT = 3$ inches
$CF = 1.5$
$R_b = 2.3$ gal/sq yd
$H_a = 0.10$ or 10 percent
$H_b = 0.05$ or 5 percent

Find the number of barrels of bitumen and loose cubic yards of aggregate needed to complete this project.

$$B = \frac{(2 \times 5{,}280 \times 23 \times 2.3 \times (1.0 + 0.05)}{360}$$

$B = 1629.32$, or *1630 barrels*

$$V = \frac{10{,}560 \times 23 \times 3 \times 1.5 \times 1.10}{324}$$

$V = 3710.7$, or *3711 cubic yards*

150. Road-Mix Pavement

Estimates of aggregates required for road mix are identical to requirements for penetration macadam pavements. The Modified Marshall Method (paras. 30 through 32) should be used for determining the amount of bitumen required. On the basis of experience, approximately 0.5 gallons per square yard of bitumen is required for each compacted inch of pavement. If a 1-inch finished pavement is to be placed, 0.5 gal/sq yd is the approximate rate of application for the bitumen. (The rate of application is based on the use of a well-graded aggregate with a 1-inch maximum particle size.) The formulas for a road-mix estimation are identical to those used for a penetration macadam.

Example: The specifications and other data for a road-mix project are as follows:

$L = 1.1$ miles $(1.1 \times 5{,}280 = 5{,}808$ feet)
$W = 23$ feet
$FPT = 2$ inches
$CF = 1.3$

Rate of bitumen application 0.5 gal/sq yd/inch of compacted pavement.

$H_a = 0.10$ or 10 percent.
$H_b = 0.05$ or 5 percent.

Find the barrels of bitumen and loose cubic yards of aggregate needed for this job.

Solution:

$R_b = (0.5$ gal/sq yd/inch of FCT) $\times$ 2 inches FCT =
$R_b = 1.0$ gal/sq yd

$$B = \frac{5{,}808 \times 23 \times 1.0 \times (1.00 + 0.05)}{360}$$

$B = 389.6$, or *390 barrels*

$$V = \frac{5{,}808 \times 23 \times 2 \times 1.3 \times (1.00 + 0.10)}{324}$$

$V = 1179.2$, or *1180 loose cubic yards*

151. Plant Mix

a. Mix Requirements by Weight. To determine the plant mix, by weight, required for a given paving area, the compacted volume in cubic feet is multiplied by the unit weight of the mix in pounds per cubic foot. Unit weight may be determined with the Marshall method as described in TM 5–530. When the exact unit weight of a plant mix has not been determined, an estimated weight of 150 pounds per cubic foot may be used. (Unit weight is usually between 140 pounds and 150 pounds per compacted cubic foot.) The formulas used for this method of plant mix determinations are:

$$T = \frac{L \times W \times FPT \times UW}{24{,}000} \qquad (8\text{–}8)$$

tons if the unit weight of the plant mix is known, or

$$T = \frac{L \times W \times FPT}{160} \qquad (8\text{–}9)$$

tons if the unit weight of the plant mix is not known where,

T = tons of plant mix.
L = length of paved area in feet.
W = width of paved area in feet.
FPT = finished pavement thickness in inches or the depth of the pavement in inches after the completion of all compaction operations.
UW = the exact unit weight of compacted plant mix in pounds per cubic foot.
24,000 = 2,000 × 12 or pounds per ton and inches per foot conversion factor.
160 = 24,000/150, where 150 is the upper range of mix unit weights usually encountered.

An example problem is given below.

Situation:

A 2-inch thickness of plant mix is desired on a 110 foot by 650 foot parking lot. Find the tons of plant mix required for this project if the unit weight of plant mix is 147 pounds per cubic feet.

Solution:

$$L = 650 \text{ feet}$$
$$W = 110 \text{ feet}$$
$$FPT = 2 \text{ inches}$$
$$UW = 147 \text{ lb/cu ft}$$
$$T = \frac{650 \times 110 \times 2 \times 147}{24{,}000}$$
$$T = 875.9, \text{ or } \textit{876 tons}$$

b. Proportioning Materials. The amount of materials that are components of the plant mix must be determined. This is best achieved by a proportionate method. The formulae for this method are difficult and are best demonstrated by the following example.

Example: The required tonnage of plant mix for a project is 800 tons. The aggregate blend is 50/40/10 (percentage course aggregate/fine aggregate/mineral filler). The bitumen content is 6 percent. How many tons of each aggregate are required?

Solution: Total aggregate percent by weight = 100 − 6 = 94 percent, or 0.94.

Coarse/aggregate = 0.94 × 50 percent = 47.0 percent by weight of the total mix.

Fine aggregate = 0.94 × 40 percent = 37.6 percent by weight of the total mix.

Mineral Filler = 0.94 × 10 percent = 9.4 by weight of the total mix.

To convert to tons the required tonnage of plant mix is multiplied by the percentage of each component of the mix. The results should be adjusted so that the sum of the tonnage of components is equal to the required tonnage of plant mix.

Coarse aggregate = 800 × 0.470 = 376.0 tons
Fine aggregate = 800 × 0.376 = 300.8 tons
Mineral filler = 800 × 0.094 = 75.2 tons
Bitumen = 800 × 0.060 = 48.0 tons
Total 800.0

(The bitumen weight was calculated as a check.)

152. Mileage Requirements

To determine the number of miles of surfacing that can be constructed with a given amount of bitumen and aggregates, the amount required for 1 mile is computed by the use of the appropriate formula from paragraphs 146 through 151 and the result is divided into the amount of available materials. In the example given below, the aggregate is the controlling factor.

Example: It is necessary to know the number of miles of single surface treatment that can be applied on a road with the materials on hand at a stockpile.

$W = 23$ feet
$R_a = 20$ lb/sq yd
$G = 30{,}000$ gallons
$T = 1{,}500$ tons
$R_b = 0.20$ gal/sq yd
$H_a = 10$ percent, or 0.10
$H_b = 5$ percent, or 0.05
T = tons per mile.

Solution:

$$T_1 = \frac{5{,}280 \times 23 \times 20 \times (1.00 + 0.10)}{18{,}000}$$

$T_1 = 148.4$ tons per mile

$$\text{Mileage with available aggregate} = \frac{1{,}500}{148.4} = 10.1 \text{ miles}$$

$$G_1 = \frac{5{,}280 \times 23 \times 0.20 \times (1.00 + 0.05)}{9} = 2833.6 \text{ gallons per mile.}$$

$$\text{Mileage with available bitumen} = \frac{30{,}000}{2833.6} = 10.6 \text{ miles}$$

The *smallest* number always governs, thus 10.1 miles is the maximum length of road that can be surfaced using materials on hand at the stockpile.

CHAPTER 9

MAINTENANCE AND REPAIR OF BITUMINOUS WEARING SURFACES

Section I. INTRODUCTION

153. Need For Maintenance

a. Maintenance and repair of roads and airfields are particularly important because of increased mobility in modern warfare. Damage caused by the weight of heavy loads, by the abrasive action of military traffic, and by combat conditions must be repaired as quickly as possible. The repairs must often be made under difficulties, such as shortages of men, materials, and equipment; a lack of time; and the possibility of continuing or imminent attack.

b. Continous maintenance cannot be overemphasized. Small repairs made immediately are much cheaper in all aspects to major repairs made at a later date.

154. Principles of Maintenance and Repair

a. For effective results, the cause of failure must be corrected. If surface repairs are undertaken without correcting a defective subgrade or base, the damage will reappear within a short time and is likely to become more extensive. A minor maintenance job that is postponed is likely to develop into a major repair job involving subgrade, base course, and wearing surface. Surface repair without correction of the basic cause is justifiable only as a temporary measure to meet immediate needs under combat conditions or other urgency.

b. Maintenance and repair of existing surfaces should conform as closely as possible to original specifications for strength, appearance, texture, and design. If the original specifications are disregarded, recurring maintenance may be necessary on areas that are below standard or differences in wear and traffic impact may result from spot strengthening.

c. Priority for maintenance and repair depends on tactical requirements, traffic volume, and the hazards that will result from complete failure of the paved area. For example, roads used for the support of tactical operations should have priority over less essential facilities. A single pothole in an intensively used road which is otherwise in excellent condition, should take priority over repair to less extensively used roads that are in poor condition.

d. Any stable material may be used for temporary repairs in combat areas or in areas where suitable material is not available and the area must be patched to keep traffic moving. Soils of good quality and masonry or concrete rubble are suitable for this purpose. All such patches must be thoroughly compacted and constantly maintained. More permanent patching should be accomplished as soon as possible.

e. Shoulders should be bladed to facilitate drainage of rainwater from the surface. Ruts and washouts should be filled. Shoulder material should be graded flush against pavement edges to restrict seepage of water to the subgrade and to prevent breaking of the pavement edge from the action of traffic on the shoulder. Material displaced from shoulders should be replaced with new material hauled in as required.

f. Repairs with bituminous materials are most successful when they are made in warm, dry weather. When breaks occur during cold weather, they should be repaired on a temporary or expedient basis to prevent progressive failures, until weather conditions permit adequate repair. Frost and moisture should be eliminated from the area with surface heaters or blowtorches, or by pouring gasoline on the area and igniting it.

155. Inspection

The purpose of maintenance inspections is to detect early evidence of defects before actual faiure occurs. Frequent inspection and followup procedures prevent minor defects from becoming serious and developing into major defects. Inspection is particularly important during rainy seasons and spring thaws, and after heavy storms. An inspection of surface defects should include investigation of the causes. Drainage systems should be inspected to assure that all drainage channels and structures are unobstructed by debris of any sort. Checkdams should be inspected for debris and excessive erosion. Causes of water ponding on surface areas or adjacent to surface areas should be investigated. Drainage inspections should be made during every storm, or immediately after a storm. Particularly thorough inspections should be made in the late fall in preparation for the winter season, and again in the spring. The value of periodic inspections with immediate maintenance cannot be overemphasized. In most cases, repair of only the surface will be necessary if adequate inspection is made.

Section II. SURFACE FAILURE AND REPAIR

156. Causes of Surface Failure

The principal causes of surface failure are subgrade or base failure, disintegration of the surface, instability, or combat failure.

157. Subgrade and Base Failure

A bituminous wearing surface is directly dependent on its base for its load-carrying capacity. Whenever the subgrade or base course fails, the part of the wearing surface that lies above the weakened area will also fail. Factors that may cause a base to fail are inadequate drainage, frost action, unsatisfactory compaction, unsatisfactory materials, and overloading.

158. Disintegration

Disintegration, or decomposition of the surface, may be the result of hardening of the bituminous film, insufficient bitumen, or stripping of the bitumen.

a. Hardening of Bituminous Film. The asphalt film starts to harden at the time the bitumen is applied, and the process continues during the entire life of the surface. This process is usually referred to as oxidation. Continuous exposure to the weather slowly hardens the bitumen, which loses its resiliency and becomes brittle. To anticipate failure from oxidation, the yearly decrease in penetration residue, or rate of oxidation, should be estimated and checked periodically. Loss of penetration value from oxidation for 3 years might be anticipated as shown in the following example:

Example: Material with an initial penetration residue of 60 would be expected to harden in a temperate climate as shown below. If the rate of oxidation remains above 30, failure from oxidation is unlikely to occur. A rate of less than 20 indicates that the pavement is brittle and that it will crack, ravel, and generally disintegrate.

Period	*Percent loss*	*Rate of oxidation (Penetration residue)*
Placement	20	48
End of first year	10	42
End of second year	10	36
End of third year	5	33

b. Insufficient Asphalt. Failure from disintegration may be caused by insufficient bitumen resulting from poorly designed mix, unsatisfactory proportioning of the aggregate and the bitumen, or inadequate mixing.

c. Stripping of the Bitumen. Water may be responsible for surface failure by causing the asphalt film to separate from the surface of the aggregate. If the aggregate absorbs too much water, the aggregate and bitumen may separate. Other causes are the use of unsuitable or insufficient bitumen, inadequate mixing, or a combination of these factors. The bitumen may also strip from dirty aggregate or be cut away by a petroleum distillate.

159. Instability

An unstable wearing surface is incapable of withstanding deformation under the impact of traffic. Causes of instability are as follows:

a. Too much bitumen.

b. Smooth aggregate.

c. Bitumen that is too soft.

d. Low density resulting from insufficient compaction.

e. Unsuitable mix design or gradation of the aggregates, and unsatisfactory placement.

f. Uncured prime.

g. Overpriming or excess tack coat.

h. Dirt between the surface and base course.

160. Combat Failure

Combat failure may be caused by bombing, shelling, or other enemy action. Nuclear airburst may harden or disintegrate a bituminous wearing surface. Continuous use of bituminous paved airfields by jet aircraft is likely to burn or scorch the surface, causing a pavement failure.

161. Potholes

Potholes are the most frequent type of failure found in bituminous wearing surfaces. Potholes may be caused by defective drainage, frost action in the base, settlement of the base, or heavy traffic. A small pothole may be surrounded by a large area that is progressively failing. A pothole may be repaired with a hot or cold premix patch or a penetration patch (paras. 169–177). If a large area has many potholes, the paving system must be entirely reworked or replaced, depending on the type of bituminous material used in the original pavement.

162. Raveling

Raveling occurs when the bond breaks down between the aggregate and the bitumen. Raveling is disintegration of the surface, with the damage starting at the top. Raveling is frequently caused by a bitumen that becomes brittle and can no longer bind the aggregate together. A scorched bitumen or any of the factors that cause disintegration may produce raveling. Raveling is repaired by applying a skin patch or a seal coat (paras. 177 and 178).

163. Cracking

Surface cracking first appears as minute hairline cracks visible only under careful scrutiny. The cracks run lengthwise of the road and appear to be more numerous toward the edges of the traveled area. Surface water may seep through the cracks to the base and cause serious base failure and the formation of potholes. Cracks wider than 1/8 inch are filled with a lean sand-asphalt mix of 2 to 3 percent MC–250, RC–250, or RT–4, and a fine-graded sand. Cracks are cleaned with compressed air. The sand-asphalt mix is broomed into the cracks until they are full, and tamped with a spading tool. The filled cracks are sealed with RC–70, RC–250, or RT–6, and covered with sand. Infrequent small cracks are also filled with RC–70, RC–250, RT–6, RS–1, or RS–2. When surface cracks and checks are so extensive that water seeps through the cracks into the base course and endangers the pavement, a sand seal is applied. The pavement should be cleaned thoroughly and not more than 1/4 gallon per square yard of bituminous material applied. An even coating of clean, dry sand should be applied directly on the bitumen and rolled until the sand is well set. The area should not be opened to traffic until the bituminous seal has set and will not pick up under traffic.

164. Rutting and Shoving

Rutting and shoving of the wearing surface may be caused by instability. Defects caused by too much cutterstock in the bitumen may be corrected in road-mix pavement by blading the material from one side of the strip to the other until the volatile substances evaporate. For excess bitumen in the mix, sufficient new aggregate is added and mixing is continued until the bitumen is evenly distributed. The mix is then reshaped and rerolled, and a seal coat may be applied. In hot-mix pavements, excess bitumen requires removal and replacement of the affected area. Weakness of the base should be corrected by reworking the pavement.

165. Corrugation

Corrugation of a bituminous wearing surface may be caused by any of the conditions discussed in the preceding paragraph and corrected in the same manner. Corrugation of a surface treatment frequently occurs when the bond has been broken between the surface and the underlying course. To repair this defect, the surface should be removed, the base reconditioned and primed, and a new surface treatment applied.

166. Burned Areas

Bituminous materials that have been burned or overheated in processing the mix become brittle and lifeless. The full depth of the pavement course constructed from such material must be removed and replaced.

167. Bleeding

Bituminous surfaces frequently bleed, or exude bitumen, in hot weather. Bleeding causes a slippery condition that is hazardous to traffic and may possibly cause the surface to become rutted and grooved. This condition should be remedied as quickly as possible. If bleeding is caused by too much bitumen or by inadequate curing, the wearing surface must be replaced or reworked. As an expedient method for light bleeding, a light, uniform coat of fine aggregate or coarse sand should be applied. Fine sand is unsatisfactory. The pavement should be rolled if possible or the traffic permitted to compact the aggregate. A light drag should be used to keep the aggregate spread uniformly, and additional applications made as required. For heavy bleeding, instructions for light bleeding should be followed, but a larger aggregate should be used instead of sand.

168. Settlements and Depressions

If settlements are caused by failure of pipes, culverts, or supporting walls, repairs to these structures must be made first. Minor settlements and depressions frequently are repaired by surface treatments. The edge of depression should be marked with chalk or paint. The surface of the pavement within the marking should be cleaned thoroughly and a tack coat applied of not more than 0.1 gallon per square yard. Materials should be used similar in character and texture to those in the adjacent pavement. The patching material should be placed, raked, and rolled. Larger settled areas are repaired with one or more applications of bituminous material on top of the existing surface, or by removing the surface course and bringing the base up to proper grade. Under suitable weather conditions, many types of bituminous surfaces may be bladed to one side of the affected area and then relaid after the base is readjusted.

Section III. BITUMINOUS PATCHES

169. Types of Patches

The types of patches used for repair of bituminous wearing surfaces are premixed patch, penetration patch, skin patch, and seal coat (surface treatment). If the damage is extensive, the entire paving system should be reworked and replaced. The following paragraphs discuss the composition and use of various patches. Instructions are given in paragraph 174 for the repair of potholes.

170. Premixed Bituminous Patching Mixes

Both hot and cold mixes are used for premixed bituminous patches. Small quantities of hot mix or cold mix often may be obtained locally or the mix may be prepared on the job. Hot mixes prepared at a central plant are generally used for extensive repair. Hot mix can be used with less delay from inclement weather than cold mix, and hot-mix patches can be opened to traffic in a shorter time. New cold patches displace easily under traffic before the volatile substances have evaporated. Also, hot-mix patches have a longer life and less tendency to ravel at the edges. Hot-mix patching material is prepared in accordance with instructions for hot-mix in paragraphs 113 through 134. Composition of premixed cold patches and the method of preparing the mix are described below.

171. Composition of Premixed Cold-Mix Patches

Cold patching mixes can be made with a minimum of equipment if the materials are carefully selected and the mix is carefully processed and stored. Cold mixes may be premixed in warm weather, stockpiled, and used several months later. Aggregate gradations for the different types of patching mixes are listed in table XII.

Table XII. Aggregate Gradation for Bituminous Patching Mixes

Sieve designation	Percentage (by weight) passing square-meshed sieves							
	I. Dense-graded plant mixes (long storage)				II. Dense-graded plant mixes (short storage)		III. Open-graded plant mixes	
	Gradation							
	I-1	I-2	I-3	I-4	II-1	II-2	III-1	III-2
1-inch							100	
¾-inch	100	100			100		90-100	
½-inch	85-95	85-95	100	100	80-85	100	60-85	100
⅜-inch	75-85	75-90	85-90	85-95	65-75	80-85	30-65	85-100
No. 4	50-70	55-75	55-75	60-80	35-50	40-55	5-25	10-30
No. 8	40-60	40-60	45-65	50-70	25-90	30-45	0-5	0-10
No. 16	35-60	35-50	35-50	40-55	20-35	25-40		
No. 200	5-10	5-12	5-10	5-12	2-7	2-7		

a. Dense-Graded Plant Mixes (Long Storage). These mixes are made with SC–800 or MC–250 at a rate of 3½ to 7 percent by weight of dry aggregate. The SC–800 and MC–250 mixes may be stored for many months and are satisfactory for temporary roads and for temporary patching of heavily traveled surfaces.

b. Dense-Graded Plant Mixes (Short Storage). These mixes are made with MC–800 or MC–3000 and RT–7 to RT–12 at the rate of 3½ to 7 percent by weight of dry aggregate. They stiffen fairly rapidly but can be stored for several weeks during hot weather.

c. Open-Graded Plant Mixes. These mixes are made with RC–800, RC–3000, RS–1, MC–250, and RT–7 to RT–12 at the rate of 3 to 5 percent by weight of dry aggregate. Mixes of this type cure within 6 to 20 hours under average weather conditions and cannot be stocked for long. They are desirable when the patch is to be used immediately.

d. Other Cold Mixes. Many other cold mixes adapted to local materials can be used. Where tar is available, mixes using aggregate gradation No. II–1 in table XII and 14 to 16 gallons of RTCB–5 or RTCB–6 for each loose cubic yard of aggregate are satisfactory. These mixes will remain in usable condition after several months of storage.

172. Moisture Content of Aggregates for Premixed Cold Patches

In most cold patching mixes, dry aggregate is required for a satisfactory mix. Damp aggregate frequently reduces the life of the patch unless emulsions are used. With some emulsions, too much moisture in the aggregate may be detrimental. During the summer months, sundried aggregate is usually satisfactory. In unfavorable weather, the aggregate may be dried with small portable dryers or small quantities of aggregate may be dried by heating in a pan over an open fire, turning the aggregate frequently to hasten drying. Covered storage is desirable for small quantities of dry aggregate.

173. Preparation of the Cold Mix

a. Proportioning. For stability, the gradation of aggregates and the amount of bitumen used are as important in patching mixes as they are in the construction of new pavements. If the ingredients are not accurately proportioned, the patch may shove or ravel and it is likely to break down in a short time. Because aggregates vary greatly in quality and grading, the quantity of bitumen used in the mix is variable. The finer the aggregate or the more dense the gradation, the more bitumen is needed to coat the increased surface area in a given volume. For most crushed stone, 2 quarts of bituminous material usually are used for 1 cubic foot of crushed stone. More bitumen will be required for fine sand. For any gradation, correct bitumen content of the mix is indicated by a dull black color with all particles coated. When the mix is thrown into a pile, the particles should slowly roll over each other or creep.

b. Application of Bitumen. The asphalt kettle or bituminous distributor usually is used to heat, transport, and apply bituminous material. An accurate thermometer is necessary for controlling temperatures. The bitumen should be heated to the mixing or spraying temperature given in table X. Safety precautions for heating bituminous materials must be observed. The bituminous material should be constantly agitated while it is being heated, either with a pump attached to the equipment or by stirring. For surface patching, sufficiently accurate distribution of bituminous material can be made with a handspray by keeping the spray nozzle at a distance from the work and moving it at a uniform rate. Bitumen is distributed from pouring pots only for crack filling. If it is necessary to use pouring pots for surface patching, the application should be broomed for uniform coverage.

c. Mixing. A pugmill or similar type of mixer gives the best results for cold mixes. If the pugmill is unavailable, one of the more workable mixes with open-graded aggregates can be blended in a mortar mixer. Another method is to spread the aggregate on an abandoned section of pavement, apply the bituminous material with a bituminous distributor, and mix with a motor grader. The mix may be used immediately or stockpiled. For small quantities, the open-graded mix may be hand-mixed with shovels.

174. Repairing a Pothole

For best results, patches should have the same density and should shed water as effectively as the surrounding area. Hand-tamping of the area below the surface is usually necessary. Successive layers of patching material should not be more than 3 inches deep. Instructions for repairing a pothole or burned area are given below.

a. The mix should be prepared as instructed in paragraph 173.

b. The area surrounding the pothole should be

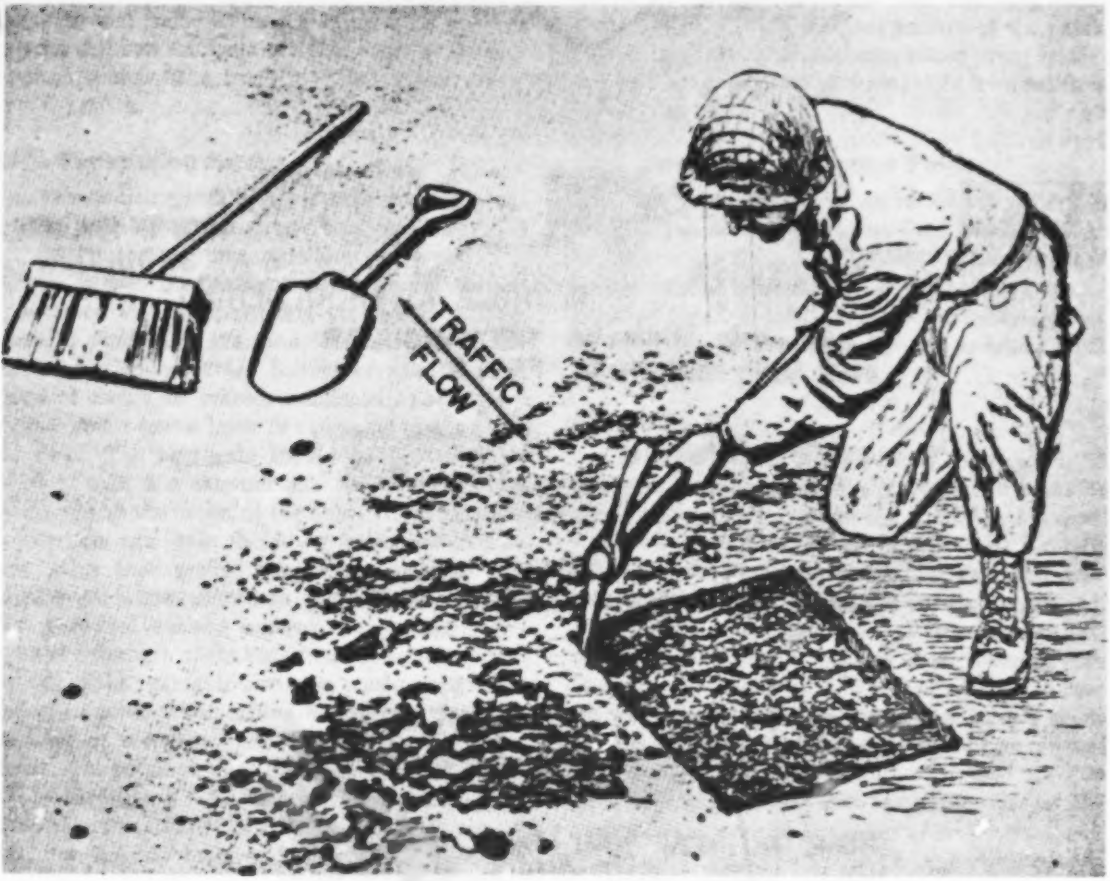


Figure 64. Correct removal of material from a failure area.

marked off with the sides of the area parallel to the direction of traffic (fig. 64). The area marked should include all surrounding weak material.

c. The failed area should be removed (fig. 65), including base material that may be weak. A rectangular hole with vertical edges should be cut to hold the patching material against the push of traffic. All loose and defective material should be removed. When a patch is placed adjacent to the shoulder of a road or airfield, the patch should be keyed to the shoulder as shown in figure 65.

d. To replace the base, the bottom of the hole should be refilled in thin layers with new base material and each layer tamped thoroughly. The base material should consist of approximately ¾-inch crushed stone. The pothole should be filled to the level of the bottom of the wearing surface if the wearing surface is more than 2 inches thick. If the wearing surface is less than 2 inches thick, it should be refilled to within 2 inches of the top of the hole.

e. A light tack coat should be applied on the new base material and on the sides and around the edges of the hole. The tack coat provides a bond between the new base material and the patching mix. An RC–2, RC–3, or RC–4 is suitable for use as a tack coat. The tack coat should become sticky before the patching mix is placed.

f. For handpatching, premixed materials should be shoveled into place, not dumped or dropped. The patch is leveled by slight raking. Dumping or dropping the premix produces a compacted area that must be turned or moved to obtain a uniform texture. Heavy raking is used only for feather-edging patches. The coarse material is pushed toward the center of the patch with the back of the

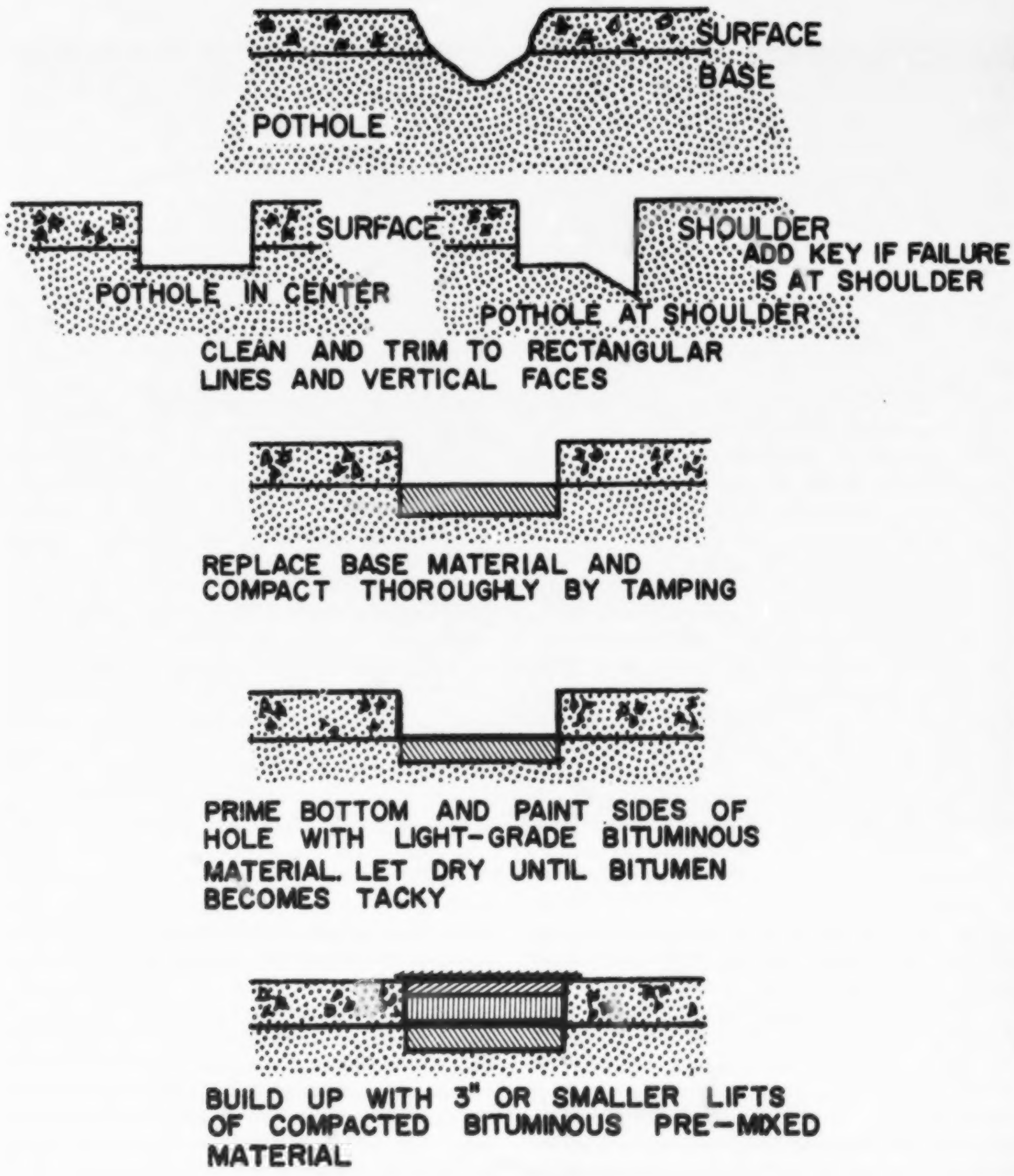

SURFACE
BASE
POTHOLE
SURFACE
POTHOLE IN CENTER
SHOULDER
ADD KEY IF FAILURE IS AT SHOULDER
POTHOLE AT SHOULDER
CLEAN AND TRIM TO RECTANGULAR LINES AND VERTICAL FACES
REPLACE BASE MATERIAL AND COMPACT THOROUGHLY BY TAMPING
PRIME BOTTOM AND PAINT SIDES OF HOLE WITH LIGHT-GRADE BITUMINOUS MATERIAL. LET DRY UNTIL BITUMEN BECOMES TACKY
BUILD UP WITH 3" OR SMALLER LIFTS OF COMPACTED BITUMINOUS PRE-MIXED MATERIAL

Figure 65. Steps in repairing a pothole.

rake. For small surface applications, the aggregate is spread with shovels as evenly as possible. Slight sweeping or raking is necessary for uniform application. Bituminous patches must be compacted to obtain the required density and to seal the aggregate. For small repairs where use of the roller is impracticable, or for larger repairs not accessible to power rollers, the patch should be hand tamped, leaving a slight crown for further compaction.

g. To compact the surface, the top of the patch should be sprinkled lightly with wet sand so that the roller and traffic will not pick up the mix while it is hardening. Tampers or rollers should be used for compaction or a truck may be driven slowly over the patch.

175. Penetration Patch

A penetration patch is made with macadam aggregate and a hot bitumen. It is essentially the mix used in penetration macadam pavement. The failure around the pothole should be cut out in accordance with the procedure for premix patches given in paragraph 174, and the cause of failure corrected when possible. Layers of suitable base material should be placed, compacted, and lightly tacked, and a coarse layer of aggregate tamped into the hole. The aggregate should be broken stone or slag, with a maximum size of 2 or 3 inches, depending on the depth of the hole. If hot bitumen is used, the aggregate should be nearly uniform in size rather than graded from coarse to fine. Aggregate gradations shown in table II for penetration macadam wearing surfaces may be used. Because the strength of the patch depends on the interlocking of the aggregate particles, crushed aggregate should be used. The bonding qualities of the bitumen are of secondary importance in this type of patch. The bitumen may be asphalt cement, 85 to 100 penetration, RT-12, or preferably an RC-3000. Rate of application is usually 1 gallon per square yard for the top inch, and ½ gallon per square yard for each additional inch of depth. The bitumen is heated and applied in accordance with instructions given in paragraph 173*b*. The process is repeated until the hole is filled to grade. After the application of the bitumen, the voids in the first layer of macadam aggregate should be keyed and choked with intermediate aggregates in accordance with the procedure outlined in paragraph 92 for penetration macadam pavement. This process should be repeated until the hole has been completely filled, leaving the final surface of the patch slightly high to allow for compaction from traffic. Excess bituminous material should be avoided in a penetration patch.

176. Modified Penetration Patch

RS-1 emulsified asphalt can be used in making a modified penetration patch less than 2 inches thick. Procedures are practically the same as for the penetration patch. Materials used for successive operations are listed in table XIII. The modified penetration patch should not be opened to traffic until it has thoroughly cured.

177. Skin Patch

A skin patch is a single surface treatment used to correct cracking and raveling on small areas of a wearing surface caused by a brittle bitumen. Skin patches seal the defective areas and recondition the wearing surface. After the damaged area is swept clean, a coat of asphalt cutback is applied. Usually an RC-800 is used at a predetermined rate. The bituminous coat is then covered with fine aggregate and lightly rolled or tamped to seal the aggregate. The aggregate usually used is about ¼-inch stone or clean coarse sand. In general, approximately 1 gallon of bitumen is used for 100 pounds of aggregate, regardless of the size of the aggregate.

178. Seal Coat

A seal coat is a single surface treatment used to seal large cracked or raveled areas. Basically, a seal coat is a sprayed application of bitumen covered with a thin layer of aggregate. The amount of bitument is dependent on the type of aggregate; usually about 1 gallon of bitumen is used for every 100 pounds of aggregate. Double surface treatments may be used if necessary.

Table XIII. Amounts of Material per Square Yard for Various Thicknesses of Modified Penetration Macadam Patches

Compacted finished thickness (in.)	RS–1 prime coat (gal)	Coarse aggregate		RS–1 first Penetration application	Intermediate aggregate		RS–1 second penetration application (gal)	Fine aggregate No. 4 to No. 16 (lb)	RS–1 seal coat application (gal)	Cover aggregate No. 4 to No. 80 (lb)	Minimum total aggregate (lb)	Minimum total emulsified asphalt (gal)
		Particle size	Pounds		Particle size	Pounds						
1½	0.20–0.30	1½ to ¾ in.	110–130	0.50–0.60	1½ to No. 8	20–30	0.60–0.70	10–15	0.25–0.35	8–12	150	1.55
1¼	.20– .30	1 to ⅜ in.	75–90	.40– .50	⅜ in. to No. 8	15–25	.50– .60	10–15	.25– .35	8–12	125	1.35
1	.20– .30	¾ to ⅜ in.	50–60	.30– .35	⅜ in. to No. 8	15–25	.45– .50	10–15	.25– .35	8–12	100	1.20
¾	.20– .30	¾ in. to No. 4	35–45	.30– .35	No. 4 to No. 16	15–25	.35– .50	10–15	.25– .35	8–12	75	1.10

Note 1. Not more than 10 percent of aggregate should be either coarser or finer than the maximum sizes indicated. Weight of aggregate assumed to be 2,500 pounds per cubic yard. If slag is used the quantity should be reduced in the ratio of weight of slag per cubic yard to 2,550. Any deficiency in the quantity of emulsified asphalt in any application should be made up for in the next application, but overapplication should not be deducted from subsequent applications.

Note 2. With limestone, or dusty aggregate, increased efficiency of penetration is obtained by sprinkling with water just ahead of each emulsion application.

Section IV. REPAIR OF CRATERS

179. Introduction

Bombs, shells, land mines, and cratering charges may produce extensive craters in roads and airfields. The use of brick for expedient repair of craters is discussed in part four. Surface damage presents no unusual repair problem, but the explosion may displace large areas of subgrade or cause instability. Drainage also may be disrupted so that water penetrating the broken surface accumulates and further softens the subgrade. Satisfactory repairs require the restoration of subgrade stability to support the traffic and prevent undue settling of the surface after repairs have been completed.

180. Procedure

Procedures for repairing a crater are as follows:

a. All damaged surfacing around the edge of the crater should be removed, as well as surfacing that is not firmly bonded to the base course.

b. Surface and base course should be trimmed to a sound vertical edge.

c. Water, mud, and debris should be removed from the crater and its sides trimmed.

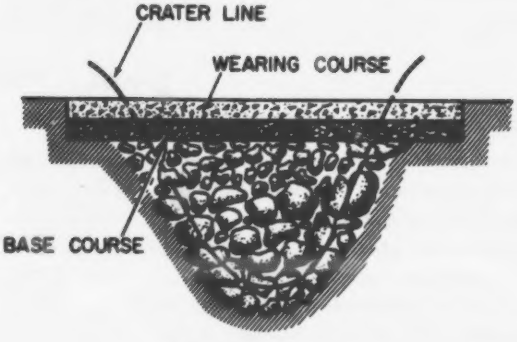
d. The crater should be filled with successive 6- to 8-inch layers up to the original level of the subgrade. Each layer should be thoroughly tamped and compacted with hand or pneumatic tamping tools. After the material has reached a suitable level, compaction equipment can be pulled or driven across the crater. Dozers may be used for compacting granular materials, but because they exert low-unit pressures, they are not satisfactory for general compaction.

e. Base course and surface should be repaired.

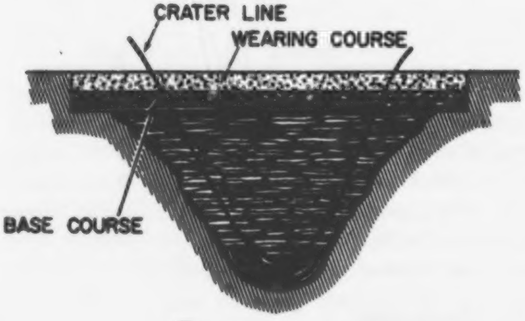
181. Backfill Materials

Gravel, rock, masonry, debris, sandy soil, or other suitable stable materials can be used in filling craters, as illustrated in 1, figure 66. Material blown from the crater can be used for much of this fill; in an emergency, material from the shoulders of roads or airfields may be borrowed and replaced later. When the situation permits and when enemy action may be anticipated, stockpiles or material pits should be prepared at convenient sites. Alternate layers of filled sandbags and tamped earth provide satisfactory subgrade compaction where suitable materials or equipment is not available. A subgrade rebuilt with sandbags and rammed earth is shown in 2, figure 66.

Caution: Hot mix should not be used on sandbags.



① SUBGRADE REBUILT WITH GRAVEL, ROCK, MASONRY DEBRIS, SANDY SOIL, OR OTHER SELECT MATERIAL



② SUBGRADE REBUILT WITH SANDBAGS AND RAMMED EARTH

Figure 66. Expedient crater repairs.

PART THREE

PORTLAND CEMENT CONCRETE PAVEMENTS

CHAPTER 10

MATERIALS

Section I. PORTLAND CEMENT

182. Composition

As used in this manual, the term cement means portland cement. Portland cements are hydraulic cements manufactured from carefully selected materials under closely controlled processes. Calcareous materials, such as limestone or marl, and argillaceous or clayey materials, such as shale or clay, are generally used in the manufacture of portland cement. Blast furnace slag is sometimes used to supply a part of the ingredients. The raw materials are crushed and pulverized, mixed in proper proportions for correct chemical composition, and fed into rotary kilns where they are calcined at a temperature of approximately 2,700° F. to form a clinker. The clinker is cooled and then pulverized with a small amount of gypsum to regulate the setting time. The pulverized product is the finished portland cement. It is ground so fine that nearly all of it will pass through a sieve having 200 meshes to the lineal inch or 40,000 openings to a square inch. When portland cement is mixed with water, a paste is formed that first sets, or becomes firm, and then hardens for an indefinite period.

183. Hydration

When cement and water are combined, a chemical reaction takes place in which heat is liberated. This is known as hydration. Strength of the concrete begins with hydration and continues to increase as long as hydration continues. At the end of a 28-day period, the relative strength increase tends to level off.

184. Standard Types

Various types of portland cement have been standardized for different uses. Selection of the type is based on the type of construction, chemical composition of the soil, economy, and speed of construction. The five types of portland cement are described below. Types I, II, and III are the most widely used; the other types are used for specific application. Air-entrained cement, which is a special type of cement, is discussed in paragraphs 210 through 216. (Air-entrained concrete may also be made by using a standard cement and an air-entraining admixture.)

185. Type I, Normal Portland Cement

Normal portland cement is used for all general construction. For pavement construction, it is used where concrete is not subject to special sulfate hazard or where heat generated through hydration will not cause an objectionable rise in temperature.

186. Type II, Modified Portland Cement

Modified portland cement generates lower heat at a slower rate than Type I. It also has improved resistance to sulfate attack. Modified portland cement is used in hot weather when moderate heat generation will tend to minimize temperature rise. In cold weather, Type I may be preferable. Type II is also intended for use as an additional precaution in areas where sulfate concentrations are higher than normal but not unusually severe.

187. Type III, High-Early Strength Portland Cement

High-early strength portland cement is used where high strengths are desired at very early periods. It is used when the forms must be removed as soon as possible so that the concrete can be put into quick service. It also is used in cold weather construction to reduce the period of time required for protection against low temperatures. Curing of high-early strength concrete usually requires 2 days at 70° F. and 3 days at 50° F. High strength at an early age can be obtained more satisfactorily and more economically with high-early strength cement than with the richer mixes of Type I cement.

188. Type IV, Low-Heat Portland Cement

Low-heat portland cement is a special cement for use where the amount and rate of heat generated must be kept to a minimum. This type of cement develops strength at a slower rate than Type I. It is usually used in large masses of concrete such as concrete dams to combat the temperature rise where heat generated during hardening may be a critical factor. This type of cement is seldom used in road or airfield construction.

189. Type V, Sulfate-Resistant Portland Cement

Sulfate-resistant portland cement is a special cement intended for use only in structures exposed to severe sulfate action, such as in areas having waters of high acid content. It has a slower rate of strength gain than normal portland cement.

Section II. WATER

190. Requirements

Water is mixed with cement to form a paste and to produce hydration. Any foreign materials in the water that tend to retard or change the chemical reaction are detrimental to concrete. Organic material and oil may inhibit the bond between the hydrated cement and the aggregate by coating the aggregate and preventing the paste from adhering to the aggregate. Many alkalies and acids react chemically with the cement and retard normal hydration. Organic material may also have the same effect. The result is a weakened paste, and the contaminating substance is likely to contribute to deterioration or structural failure of the finished concrete. Required properties are cleanliness and freedom from organic material, alkalies, acids, and oils. In general, water that is acceptable for drinking may be used for concrete.

191. Sea Water

Sea water may be mixed with cement with satisfactory results except that strength of the concrete may be reduced approximately 10 to 20 percent. As a field expedient, the water-cement ratio may be decreased to offset the loss of strength. As a general basis for strength reduction (if the water-cement ratio cannot be changed for some reason), concrete pavement made from ordinary ocean water (average salt content) should have the design thickness multiplied by 1.15 to obtain a thickness of equal strength. Pavement made from water obtained from a landlocked sea (ex: the Dead Sea), which has an extraordinarily high salt content, should have the design thickness multiplied by 1.25 or 1.30 to obtain a section of equal strength. Salt water acts as an accelerator much the same as calcium chloride does except that salt decreases the strength. The use of sea water in reinforced concrete should be avoided if possible. Accelerators are discussed in paragraph 201.

192. Well (Sulphur) Water

Water with a high sulfate content, such as that found in some wells or in streams around underground mines, may be a source of water for concrete mixing. This type of water should not be used unless necessary. If this type of water is the best available, sulfate-resistant cements should be added. Generally, "sulphur" water that is not unpleasant to drink will give excellent results with Type V, good results with Type II, and fair results with other types. If the water contains enough sulfates to make it unpleasant to drink, Type V will yield good results, Type II fair results, and all other types will give marginal or unsatisfactory results. Some water containing sulfates and found near underground mines may also contain acids or alkalies. The addition of an accelerator to mixes made from this type of water may offset the harmful effects of these contaminants.

193. Introduction

Aggregates are combined with cement paste primarily as a filler, but their physical characteristics affect the proportions and economy of the mix as well as the qualities of the finished concrete. Crushed rock and natural deposits of sand and gravel are most commonly used, but artificial aggregates, such as blast furnace slag or specially burned clay, may be used if natural aggregates are unavailable. In some instances, production of satisfactory expedient aggregate may be combined with clearing operations by crushing rubble from demolished structures.

194. Types of Aggregate

Both fine and coarse aggregate are used in the production of concrete. The two types should be combined in a well-graded mix (fig. 67) to produce an almost voidless building stone that is strong and durable. For portland cement concrete, fine aggregate is aggregate that will pass the No. 4 sieve and be retained on the No. 100 sieve, with 2 to 10 percent passing the No. 100 sieve. Fine aggregate is used to fill the voids between the coarse aggregate particles. Its use reduces the amount of paste required. Coarse aggregate is aggregate that will pass the 3-inch sieve and be retained on a No. 4 sieve. It is used primarily as a filler. For pavements, maximum size of the coarse aggregate should not exceed 2 inches or one-third the thickness of the slab. The larger the maximum size particle, within recommended limits, the less paste is required for coating the aggregate.

195. Characteristics

a. Requirements. To produce finished concrete of high quality, aggregate should be clean, hard, strong, durable, and round or cubical in shape. These characteristics are discussed below. Tests for bulk specific gravity, (saturated-surface-dry) and absorption of both fine and coarse aggregate, for surface moisture of fine aggregate, and for organic matter in sand are described in TM 5-530.

b. Cleanliness. Harmful ingredients, such as organic matter, dirt, silt and clay, chemicals, or other contaminating materials, may contribute to deterioration of the finished concrete by inhibiting the bond between the cement paste and the aggregate or by reacting chemically with the constituents the cement. Excessive fines may also inhibit bor ing and produce a mix that is structurally weak a susceptible to breakdown by weathering. Light ganic material, dirt, silt, and clay should be wasl out of the aggregate.

c. Moisture Condition. For determination of r proportions, the aggregate should be in a saturat surface-dry condition or adjustment made in water-cement ratio to compensate for the differ amount of water contained in the aggregate. TM 5-530.

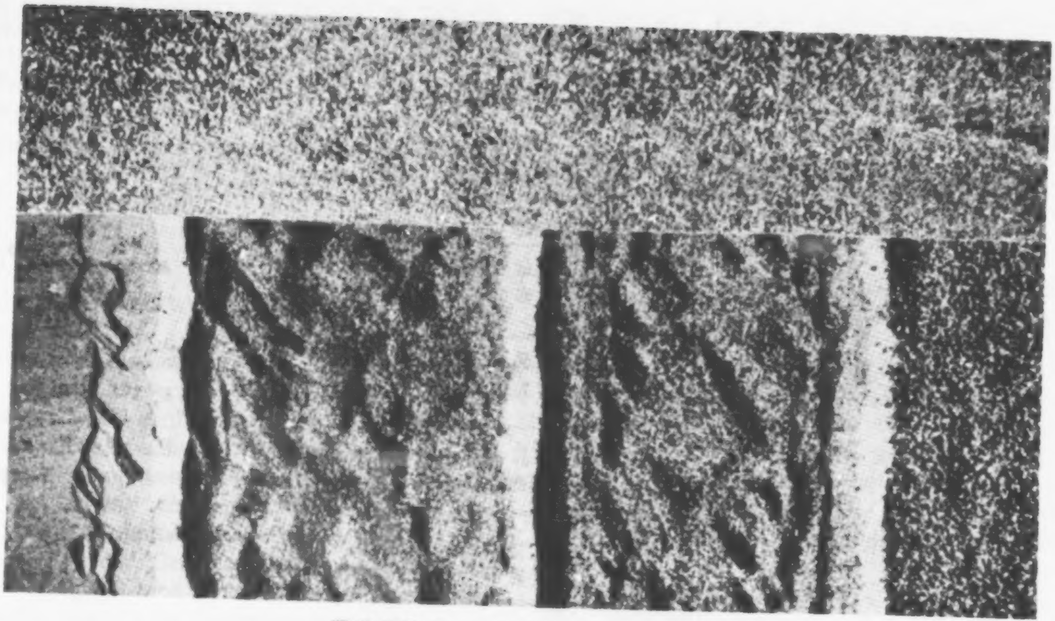
d. Strength and Durability. Aggregate sho be strong and resistant to abrasion from weather and wear. Weak, friable, or laminated particles aggregate, or aggregate that is too absorptive, likely to cause deterioration of the finished c crete. Visual inspection will frequently discl weakness in the coarse aggregate.

196. Gradation

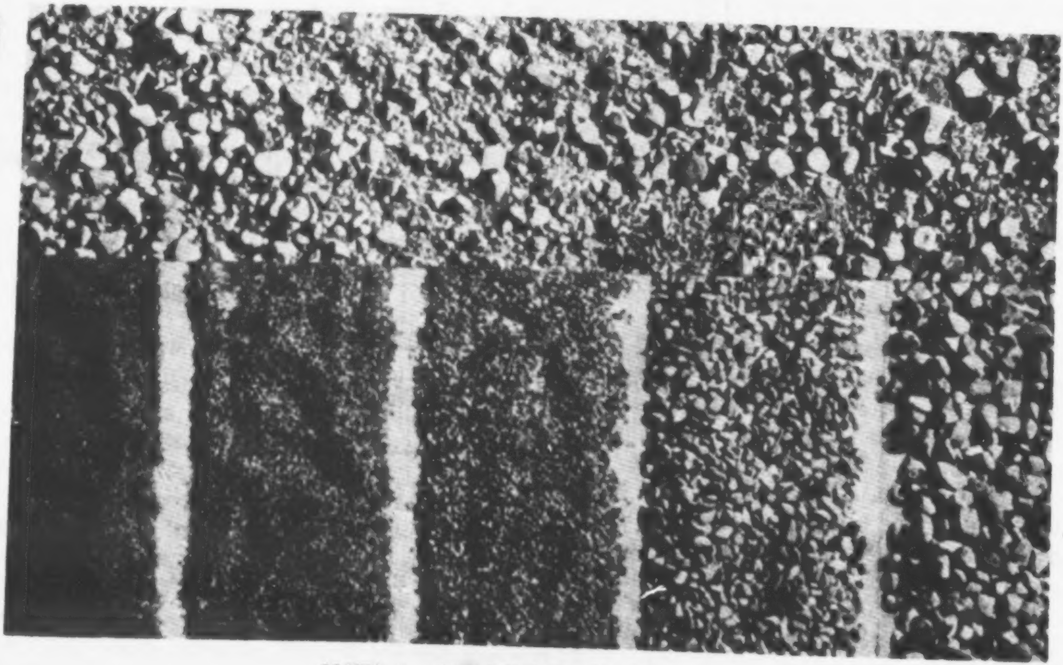
Gradation, as well as maximum size, affects relative proportions, workability, and economy the mix, and watertightness and shrinkage of finished concrete. In general, aggregate used concrete must be well graded to produce a de mass with a minimum volume of voids. Aggreg that is not well graded may reduce the strength the finished concrete and will increase the cost the mix because of the additional paste requi to fill voids. Gradation of aggregates is discussec TM 5-530. Recommended limits for fine and coa aggregate are listed in table XIV.

197. Fineness Modulus of Sand

The fineness modulus (FM)of sand is an emp cal factor obtained by adding the cumulative p centages of a sample of aggregate retained on e of a specified series of sieves and dividing the re by 100. The sieves ordinarily used for determin the fineness modulus are the Nos. 100, 50, 30, 8, and 4. The fineness modulus is an index of relative fineness or coarseness of sand in the c crete mix. It is used to determine the relative p portions of sand to gravel. The fineness modu is not an indication of the gradation. In gene fine aggregate with a very low or high fineness m



POORLY GRADED SAND



WELL GRADED SAND

Figure 67. Samples of well and poorly graded sands.
From "Design and Control of Concrete Mixtures," courtesy of Portland Cement Association.

Table XIV. Recommended Aggregate Gradation Limits for Portland Cement Concrete

Size number	Nominal size (sieves with square openings)	Amounts finer than each laboratory sieve (square openings), percent by weight											
		4 in.	3½ in.	3 in.	2½ in.	2 in.	1½ in.	1 in.	¾ in.	½ in.	⅜ in.	No. 4 (4760-micron)	No. 8 (2380-micron)
3, 5, 7	2 in. to No. 4	-------	-------	-------	100	95–100	70–90	35–70	50–20	10–30	20–5	0–5	-------
4, 6, 7	1½ in. to No. 4	-------	-------	-------	-------	100	95–100	60–85	35–70	25–50	10–30	0–5	-------
5, 7	1 in. to No. 4	-------	-------	-------	-------	-------	100	95–100	60–80	25–60	15–45	0–10	0–5
6, 7	¾ in. to No. 4	-------	-------	-------	-------	-------	-------	100	90–100	55–80	20–55	0–10	0–5
7	½ in. to No. 4	-------	-------	-------	-------	-------	-------	-------	100	90–100	40–70	0–15	0–5
3	2 to 1 in.	-------	-------	-------	100	90–100	35–70	0–15	0–15	0–15	-------	-------	-------
4	1½ to ¾ in.	-------	-------	-------	-------	100	90–100	20–55	0–15	0–10	0–5	-------	-------

ulus is not as satisfactory for concrete as medium nd.

198. Blending

If the gradation of an aggregate does not meet recommended limits due to the lack of certain particle sizes, or if it has an abundant amount of certain particle sizes, it will be necessary to blend the material to meet requirements. Deficiencies of this nature may be corrected by adding the missing particle sizes, or smreening out the abundant particle sizes.

Section IV. ADMIXTURES

199. Introduction

Admixtures used with portland cement are air-entraining agents, accelerators, retarders, plasticizers, cement-dispersing agents, concrete densifiers, and waterproofing agents. They are used to change the characteristics of the mix or of the finished concrete. Use of admixtures is not recommended if the end result can be achieved more economically by altering mix proportions. Discussion in this manual is limited to admixtures used in concrete pavements. Cement-dispersing agents, concrete densifiers, and waterproofing agents are generally used only for the construction of structural members.

200. Air-Entraining Agents

Many different air-entraining agents may be used produce air-entrained concrete. In general, air-ntraining agents are liquids derived from natural wood resins, animal or vegetable fats or oils, and various wetting agents, such as alkali salts or sulfonated organic compounds and various water-soluble soaps. Air-entraining agents are added to the mix to increase resistance to the action of the frost and chemicals. They also increase workability of the mix. Air-entrained concrete is discussed in paragraphs 210 through 216.

201. Accelerators

An accelerator is used in a concrete mix to accelerate hydration, which increases the heat generated and produces high-early strength of the finished concrete. Calcium chloride ($CaCl_2$) is the most widely used accelerator. It may be used whenever it will prove economical and whenever the increased hydration will not cause a flash set or undue shrinkage. The usual quantity of calcium chloride used is about 1 to 2 percent by weight of the cement, which increases flexural strength by 40 to 90 percent at 1 day and 5 to 35 percent at 3 days when moist cured at 70° F. At a tempera-ure of 40° F, strength increases are lower. Acceleration is usually greater within the first 3 days. With the same water-cement ratio, ultimate strength at 1 year is approximately the same or slightly higher for cement mixed with calcium chloride. Because calcium chloride increases workability of the mix, lower water-cement ratios can be used with subsequent increases in strength. Calcium chloride should not be used for curing, either on the surface or as an admixture. Sodium chloride (NaCl) will also accelerate hydration, but it will reduce the strength of concrete.

202. Retarders

A retarder is used when it is necessary to slow down the rate of hydration so that concrete can be placed and consolidated properly before it becomes initially set. Retarders are used when there is danger of flash set, when the heat of hydration is expected to be excessively high, when the cement may come in contact with high ground temperature (as in grouting operations), or when concrete is to be laid during hot weather. Retarders also are used to increase strength and durability when concrete is to be revibrated before its initial set. Many commercial products are available that will retard the set of concrete. Basically, retarders are fatty acids, sugars, and starches.

203. Plasticizers

Admixtures used principally for other purposes are often used as plasticizers to increase workability of the mix. Air-entraining agents, discussed in paragraph 200, are effective plasticizers; calcium chloride and other pozzolans also may be used. Lime is one of the most widely used plasticizers. Finely pulverized inert fillers increase the workability of a mix deficient in fines, but increase the mixing-water demand. Plasticizers should not be used as a substitute for proper aggregate gradation.

204. Pozzolans

A pozzolan is a siliceous material that becomes cementatious when combined with lime. Pozzolans are usually used as cement replacement agents. Examples of pozzolanic materials are fly ash, volcanic ash, calcined diatomaceous earth, and calcined shale. Fly ash, the most widely used pozzolan, is a waste product from large, powdered-coal-burning furnaces. Used as a cement replacement agent, fly ash can replace up to 50 percent of the cement by weight. The use of fly ash changes practically all the properties of concrete in both its plastic and hardened state. In general, fly ash improves the workability of plastic concrete. If the same weight of aggregates is used in a mix, it has been found that identical slumps can be obtained from cement fly ash mixtures having lower water-cement ratios than comparable mixes using straight portland cement. While the fly ash acts as a plasticizer making the mix more workable, it also produces a great reduction in both bleeding and segregation.. Th heat of hydration is also greatly reduced. It h been found that when fly ash cement mixes and straight cement mixes are compared, fly ash will cause a 40 to 50 percent reduction in heat of hydration as compared to that of modified portland cement. The concrete will not gain strength as fast as 100 percent portland cement concrete during the first month of hydration, but after a hydration period of 1 year, fly ash concrete will produce strengths equal to, or greater than, 100 percent portland cement concrete. Tests show that the development of durability parallels that of strength. Although slow to develop in the early stages of hydration, fly ash cement, after 1 year of hydration, will have durability far superior to that of 100 percent portland cement concrete.

Section V. MATERIALS HANDLING AND STORAGE

205. Aggregate

Concrete quantities which justify batch plants also justify stockpiles of aggregates at the batch plant and at the crushing and screening plants. Stockpiling is identical to the method described for bituminous pavements. Stockpiles prevent shortage at the batching plant or paver caused by temporary production or transportation difficulties.

206. Cement

a. Storage. Sacked cement that is to be stored for a long time should be placed in a warehouse or shed that is as airtight as possible. The floor of the shed should be above ground and all cracks in the wall closed. Sacks should be stacked close together to reduce air circulation but should not be stacked against the wall. The concrete mixer and storage shed should be as close together as possible. The cement sacks should be stacked on a raised wooden platform as shown in figure 68. Note that the tarpaulins extend over the edge of the platform to prevent rain from collecting on the platform and thereby reaching the bottom sacks. Tarpaulins may be used for protection against moisture if the amount of cement to be stored is small or if it is to be stored for a short time. Cement must be kept dry. If it does not come into contact with moisture, it will retain its quality indefinitely. When sacked cement is packed too tightly and stored over a long period of time, it may develop warehouse pack, although the cement may retain its quality. This condition can usually be corrected by rolling the sack on the floor. At the time of use, the cement should be free flowing and free from lumps. If the lumps are hard to break up, the cement should be tested to determine its suitability. (See TM 5–530.)

b. Handling. If portland cement is handled bulk, which is not too likely in a theater of operations, it is blown through ducts from railroad cars to a cement bin and weighing hopper. This hopper stands astride the trucks, beyond the aggregate batcher, and dumps the bulk cement into each batch. If the cement is in sacks, which is usual practice in a theater of operations, the sacks are opened

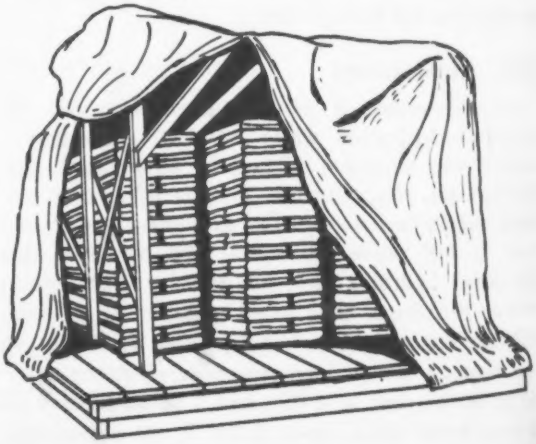


Figure 68. Cement stored under a tarpaulin.

and dumped into each batch from a roadside platform. The cement bags are stacked on a platform or on dunnage and covered with canvas tarpaulins or roofing paper. When available, tightly fitted canvas covers for the truck bodies should be used to prevent wind loss and to avoid damage from light showers. Length of haul and weather conditions may make it advisable to dump unopened sacks of cement into each batch, to be opened upon arrival at the mixer. Platforms for loading the sacks of cement onto trucks may be located at any point along the route from batching plant to paver. Hand trucks and roller conveyors are useful at cement-loading points. Standard sacks of cement are tossed by two men lifting and swinging in rhythm, and paper sacks are emptied by cutting the underside lengthwise with a sharp, curved, linoleum knife and pulling the empty sack free. Men handling cement should wear goggles, respirators, and gloves and should avoid skin irritation by precoating exposed surfaces with vaseline or neatsfoot oil.

207. Water

Water should be stored near the mixer in tanks or water trailers. Water containers should be clean and rust-free.

CHAPTER 11

CHARACTERISTICS OF CONCRETE

Section I. DESIRABLE PROPERTIES

208. Plastic Concrete

a. Essential Qualities. The quality of the hardened concrete is largely dependent on the quality of the plastic concrete. The curing process also contributes to attainment of the specified design criteria. Because the consistency of the mix may vary, careful adherence to design criteria is extremely important. When the ingredients are tested for suitability, the only variable factor in the plastic mix may be in the proportioning, which must be accurate. Plastic concrete should be workable, free from segregation of the coarse aggregate, and of uniform quality.

b. Workability. Workability of the plastic mix is the relative ease or difficulty of placing and consolidating concrete in the form. The consistency of the mixture shall be maintained as necessary to obtain the workability required for the specific conditions and method of placement. The slump test which is used to measure the consistency of the mix is a measure of workability as well. To perform this test, the mixed concrete is placed in a standard cone in three respective layers, approximately equal volume, and each layer is rodded 25 times. The last layer is placed, rodded, and struck off. Then the cone is lifted vertically away from the plastic concrete, which is allowed to slump, or settle. The measurement of settlement below the top of the cone is recorded as a measure of workability of the mix. The maximum or minimum slump will be in accordance with specifications for the particular job. If constant quantities of materials are used, the slump should remain constant. Any marked variation in slump or consistency will immediately indicate a deviation from the mix design. An investigation should be made immediately to determine the cause.

c. Nonsegregation. Plastic concrete should be handled and placed so that it is free from segregation of the coarse aggregate and completely homogeneous. To prevent segregation, the plastic concrete should not be dropped, or allowed to fall free, for a distance greater than 3 to 5 feet.

d. Uniformity. For uniformity of the mix, every batch should be accurately proportioned in accordance with design criteria. Uniformity increases the economy of the mix and improves the quality of the hardened concrete.

209. Hardened Concrete

a. Essential Qualities. Essential qualities of hardened concrete in pavement are uniform flexural strength and durability.

b. Strength. Concrete pavements must have sufficient flexural strength to carry the required load. To attain the desired strength, the most important factor is the ratio of water to cement. In general, not more than 7 gallons and not less than 4 gallons of water are required for each sack of cement. Although a high water-cement ratio increases the yield of each sack of cement, a thin paste is inherently weak and evaporation of excess water during the curing process leaves voids that will reduce the strength of the hardened concrete.

c. Durability. Durability of finished concrete is the ability of the artificial stone to resist the effects of the weather, such as the action of the wind, frost, snow, ice, and the combined effects of wetting-drying and freezing-thawing cycles; the chemical reaction of soils or the effects of salts; and abrasion. Durability is affected by climate, thickness of pavement, and exposure. As the water-cement ratio is increased above the minimum of 4 gallons per sack, the durability is likely to decrease correspondingly

Section II. AIR-ENTRAINED CONCRETE

210. Introduction

Air-entrained concrete is a comparatively recent development used to reduce scaling, particularly in areas where concrete must be resistant to severe frost action and impervious to the harmful effects of chemicals used for melting snow and ice. Air-entrained concrete is more durable than normal portland cement concrete, but strength is slightly reduced. The air-entrained mix has increased workability and less segregation.

211. Composition

Air-entrained concrete consists of cement, sand, water, and gravel. In addition, millions of tiny air bubbles ranging from a few microns up to 75 microns in diameter are entrained, or diffused, in the cement paste. Calculations indicate that as many as 400 to 600 billion air bubbles are entrained in a cubic yard of concrete. Specified percentage by volume usually requires 4½ percent entrained air, with an acceptable range of 3 percent to 7 percent. Although normal portland cement concrete usually contains from ½ to 1½ percent of air, this air is usually entrapped in the form of voids and is not dispersed uniformly throughout the mix.

212. Production

a. Method. Air-entrained concrete may be produced by two methods. First, air-entraining agents may be added during the cement manufacturing process. These types of cement are denoted by a suffix "A" (ex: Type I–A) on the bag. This method is less desirable because the air content cannot be changed at the work site and the agents may lose their effectiveness after long storage. The best control is offered by the second method, the addition of an air-entraining admixture at the site. This commercially prepared agent should be used in quantities specified by the manufacturer. The agent should not be diluted with water unless specified. Types I, II, and III portland cement are the types commonly utilized for air-entrainment. Air content of the mix must be rigidly controlled to obtain the desired uniformity.

b. Temperature. The amount of air-entraining agent required to produce any given air content increases with an increase in concrete temperature. Therefore, frequent tests should be made of air contents particularly if there are changes in the concrete temperatures.

c. Mixing Time. To insure proper air content, normal concrete should be mixed for about 1 to 2 minutes. Air content increases about 1 percent as the mixing time is increased from 1 to 5 minutes; from 5 to 10 minutes, air content remains unchanged. Beyond 10 minutes it gradually decreases until after 60 minutes the air content is identical to the 1-minute mixing period.

d. Vibration. Vibration of air-entrained concrete for 1 minute or more in the same spot reduces air content 15 to 20 percent. Internal vibration reduces air content more than external vibration. Vibration is discussed in paragraph 282.

213. Measuring Air Content

The three methods of measuring air content of freshly mixed concrete are the pressure method, the gravimetric method, and the volumetric method. The method most widely used is the pressure method. The principle of the pressure method is that the volume of gas at a given temperature is inversely proportional to the pressure to which it is subjected. An air meter is calibrated so that the percentage of entrained air is read when a known volume of concrete is subjected to a known pressure (TM 5–530).

214. Slump

The addition of entrained air to a mix will allow the slump to be decreased. A 3-inch slump for nonair-entrained pavement mixes is usually necessary for good workability. The same workability may be obtained from an air-entrained mix with a 1- to 2-inch slump. This increase in workability is due to the fatty character of the mix. The whipped cream-like effect of air-entrained concrete allows a slump reduction which maintains the original degree of workability. The reduction of slump allows the water-cement ratio to be decreased, thus increasing the strength.

215. Correction for Strength

a. The strength of air-entrained concrete is inversely proportional to the percentage of entrained air. With all other factors constant, strength is reduced about 5 percent for 1 percent of entrained air. Strength increases may be obtained by decreasing the sand and water in the mix. This allows pavements to be designed for a given thickness and mix, without major changes for air entrainment.

Chapter 12 discusses the method of properly adjusting the mix for entrained air.

b. Entrained air causes voids in concrete, thus reducing the strength, but the workability and slump changes will allow a water-cement ratio reduction, increasing the strength. As a general guide, an air-entrained concrete with the slump decreased and the strength properly adjusted will yield a mix having strength almost equal to an original nonair-entrained mix. The capillary air voids caused by the evaporation of extra water added for workability is replaced by minute, evenly distributed air void (greater uniformity) of entrained air.

216. Durability

Air-entrained concrete is much more resistant to weathering than nonair-entrained concrete. Air-entrained concrete should be used whenever possible for this reason. The reasons for this increase of durability are beyond the scope of this manual.

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CHAPTER 12

MIX DESIGN

Section I. DESIGN CRITERIA

217. Introduction

This chapter discusses only the design of concrete paving mixes. Structural concrete mix design is discussed in TM 5–742. Both the flexural (beam) strength and the compressive strength of the hardened mix are used in design. Flexural strength is a measure of the bridging strength of the concrete and is used in designing nonreinforced concrete pavements. Compressive strength measures the resistance to a direct load. The design strength tests for road pavements are usually made at the end of 28 days. For permanent-type airfield pavements, design is usually based on 90-day strength, an increase of approximately 10 percent over the 28-day strength.

218. Selection of Water-Cement Ratio

The water-cement ratio is selected to conform to requirements for flexural strength and durability. Durability is required for long life and low upkeep. Of particular importance is high resistance to exposure and freezing. Age-flexural-strength relationships for Types I and III portland cement for varying ages are shown in figure 69. Recommended water-cement ratios for durability for various exposures are shown in table XV. The lowest water-cement ratio that will satisfy requirements for both flexural strength and durability should be selected. The water-cement ratio for flexural strength is read directly from the data plotted in figure 69 and adjusted for durability. For example, from figure 69, the water-cement ratio for Type I portland cement at 28 days at 600 psi, read from the bottom of the curve, is 5¼ gallons per sack. If the requirement for durability from table XV is a water-cement ratio of 5½ gallons per sack, 5¼ is selected as the lowest ratio that will satisfy requirements for both flexural strength and durability. Once the water-cement ratio is selected, it should not be changed except for air-entrainment adjustments.

219. Selecting Fine Aggregate

Fine aggregate is used to fill the spaces remaining in the coarse aggregate and to increase workability. Very fine sands are uneconomical because they require more water-cement paste; coarse sands give harsh unworkable mixes. In general, fine aggregates that have a smooth gradation curve produce the most satisfactory mixes. For economy, not more than 10 percent of the fine aggregate should pass the No. 100 sieve. For increased workability, it is desirable that 3 to 4 percent pass the No. 100 sieve.

Table XV. Water-Cement Ratios Recommended for Durability for Various Exposures.

Pavement slabs directly on ground	Severe or moderate climate, wide range of temperature, rain and long freezing spells or frequent freezing and thawing (gals/sk)			Mild climate, rain or semi-arid; rarely snow or frost; no hard freezing (gals/sk)		
	Thin sections	Moderate sections	Mass sections	Thin sections	Moderate sections	Mass sections
	0–8"	8" to 24"	Over 24"	0–8"	8" to 24"	Over 24"
*Wearing slabs	5½	5½	5½	6	6	6
Base slabs	6½	6½	6½	7	7	7

* New construction of roads or airfields will usually be under the wearing slab criteria.

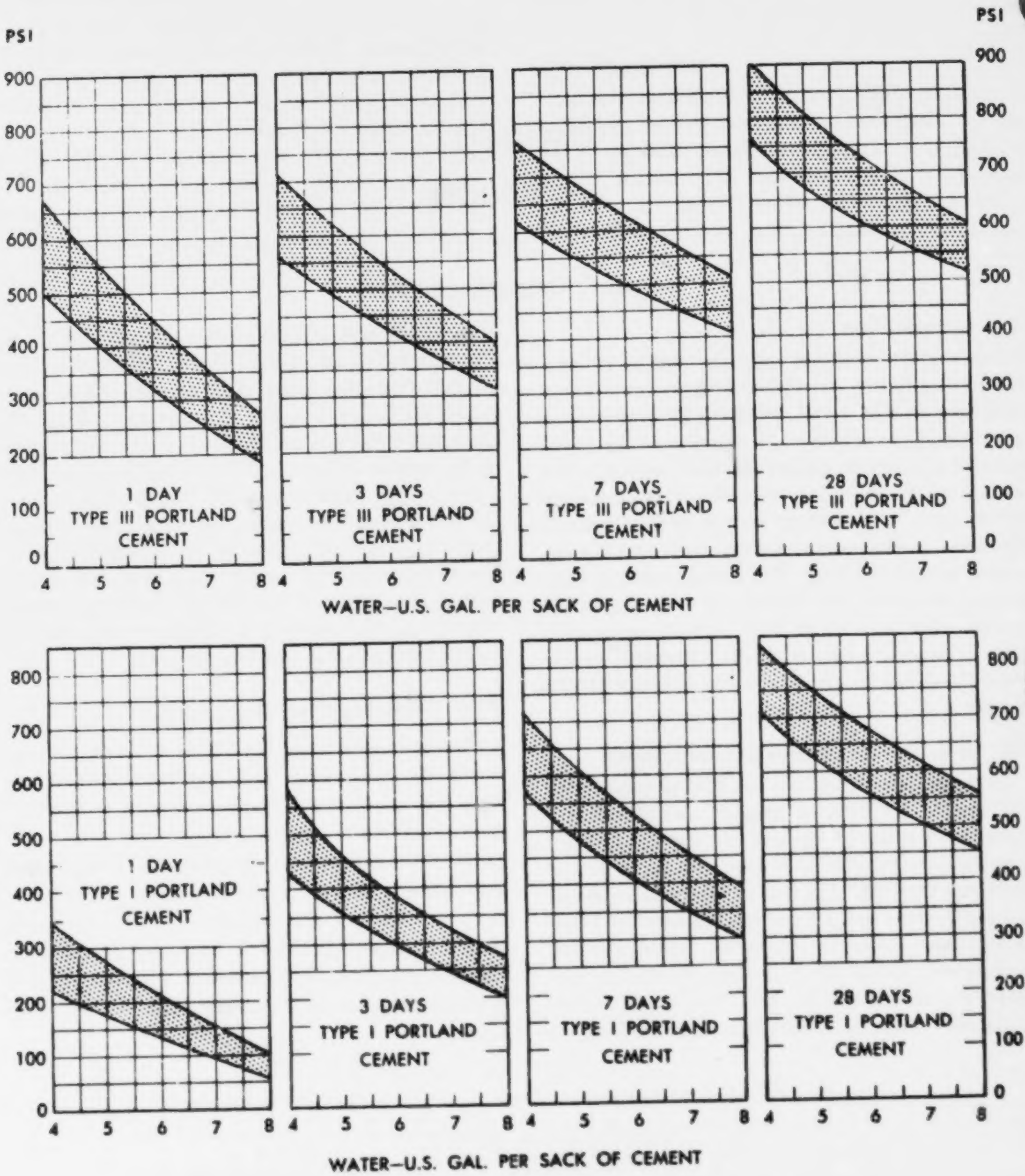


Figure 69. Age-flexural-strength relationships for Types I and III Portland cements.
From "Design and Control of Concrete Mixtures," courtesy of Portland Cement Association.

220. Selecting Coarse Aggregate

Coarse aggregate should be graded to the maximum size which, in general, should not exceed one-third the thickness of the slab. Assuming a smooth gradation of both coarse and fine aggregate, the larger the size of the coarse aggregate, the less paste will be required to produce satisfactory concrete. For most TO paving operations, the maximum aggregate size will be 2 inches or less.

221. Selecting Workability

a. The slump test, described in TM 5–530, has been used as a measure of workability in the past. A slump test of air-entrained concrete will *not* yield a reliable measurement of workability. Generally, a 3-inch slump for nonair-entrained concrete will have approximately the same degree of workability as a 1- to 2-inch slump for an entrained air mix. This difference in slump should be kept in mind when using the slump test to check the workability of a mix.

b. Workability of the mix is governed largely by the amount of aggregate added to the mix. The gradation of the sand and the relative percentage of sand to gravel also affect workability. Because more aggregate is required and less cement, a stiff mix is more economical than a fluid mix. If too much aggregate is used, however, the mix may be dry and crumbly, it will be difficult to place in the forms, and voids may be left in the concrete. However, a stiffer than normal mix may be used if mechanically vibrated. A mix that is too fluid, with too little aggregate, allows the heavy particles of aggregates to settle at the bottom and the fines to rise to the top.

222. Methods of Mix Design

The two methods of mix design used to proportion the quantities of cement, water, and aggregate used in the concrete are the book method and the trial batch method. The book method is a theoretical method of design making use of laboratory data. Because of variation in materials, the book method should be used as a design basis with adjustments made in the field by the trial batch method.

Section II. BOOK METHOD

223. Selecting Mix Proportions

When the water-cement ratio, type and size of aggregate, and workability of the mix have been selected, the data in table XVI may be used to obtain quantities of ingredients for a trial mix of medium consistency and the yield in cubic feet per sack of cement. Data in this table are based on a 3-inch slump with aggregate in a saturated-surface-dry condition. Use of the table is illustrated in the following example, assuming that—

FM of sand = 2.30
Slump = 3 inches
Water-cement = 6 gal/sk
Maximum size of coarse aggregate = 2 inches

Material requirements per sack of cement and yield in cubic feet per one-sack batch obtained from table XVI are as follows:

Quantities per sack of cement

Sack of cement = 94 lb
Sand = 200 lb
Gravel = 400 lb
Water = 6 gal
} Yield per one-sack batch = 4.91 cu ft

Materials required per cubic yard

Cement = 5.5
Sand = 1,100
Gravel = 2,200
Water = 33 gal
} Yield = 1 cu yd

224. Adjustment for Variation in Slump

Pavement mixes often require a slump of other than 3 inches; thus a correction must be made to the figures obtained from table XVI. For each decrease of 1 inch in slump, sand should be decreased by 3 percent, and water by 1 gallon per cubic yard of concrete. To increase the slump, the sand and water content should be increased.

Example: Adjust the mix given in the example in paragraph 223 for a 2-inch slump.

Solution:

Materials required per cubic yard

Cement = 5.5 sacks (no change)
Sand = 1,100 — (0.03 × 1,100) = 1067 pounds
Gravel = 2,200 pounds (no change)
Water = 33 — 1 = 32 gallons

225. Adjustment for Moisture

In the field, aggregates usually contain moisture in excess of the saturated-surface-dry condition. Excess moisture added to the mix will alter the water-cement ratio and reduce flexural strength and durability by increasing the capillary voids in the finished concrete. Fine aggregate may contain as much as 1 gallon of surface water per 100 pounds; the amount usually varies from 2 to 6 percent,

Maximum size of aggregate, inches	Water, gallons per sack of cement	Water, gallons per cu yd of concrete	Cement, sacks per cu yd of concrete	Fine aggregate—per cent of total aggregate	Fine aggregate—lb per sack of cement	Coarse aggregate—lb per sack of cement	Fine aggregate—lb per cu yd of concrete	Coarse aggregate—lb per cu yd of concrete	Yield, cu ft of concrete per sack of cement	Fine aggregate—per cent of total aggregate	Fine aggregate—lb per sack of cement	Coarse aggregate—lb per sack of cement	Fine aggregate—lb per cu yd of concrete	Coarse aggregate—lb per cu yd of concrete	Yield, cu ft of concrete per sack of cement	Fine aggregate—per cent of total aggregate	Fine aggregate—lb per sack of cement	Coarse aggregate—lb per sack of cement	Fine aggregate—lb per cu yd of concrete	Coarse aggregate—lb per cu yd of concrete	Yield, cu ft of concrete per sack of cement
				With Fine Sand—Fineness Modulus 2.20-2.60						With Medium Sand—Fineness Modulus 2.60-2.90						With Coarse Sand—Fineness Modulus 2.90-3.20					
¾	5	38	7.6	43	170	230	1290	1750	3.56	45	180	220	1370	1670	3.56	47	185	210	1370	1595	3.56
1	5	37	7.4	38	160	255	1185	1890	3.65	40	165	250	1220	1850	3.65	42	175	240	1295	1775	3.65
1½	5	35	7.0	34	150	300	1050	2100	3.86	36	160	290	1120	2030	3.86	38	170	280	1190	1960	3.86
2	5	33	6.6	31	150	335	990	2210	4.09	33	160	325	1055	2140	4.09	35	170	315	1120	2080	4.09
¾	5½	38	6.9	44	195	250	1345	1725	3.91	46	205	240	1415	1655	3.91	48	215	230	1480	1585	3.91
1	5½	37	6.7	39	180	285	1205	1910	4.03	41	190	275	1270	1840	4.03	43	200	265	1340	1775	4.03
1½	5½	35	6.4	35	175	320	1120	2050	4.22	37	185	315	1185	2015	4.22	39	195	305	1250	1950	4.22
2	5½	33	6.0	32	175	370	1050	2220	4.50	34	185	360	1110	2160	4.50	36	195	350	1170	2100	4.50
¾	6	38	6.3	45	225	275	1420	1730	4.29	47	235	265	1480	1670	4.29	49	245	255	1540	1610	4.29
1	6	37	6.2	40	205	305	1270	1890	4.36	42	215	295	1335	1830	4.36	44	225	285	1395	1770	4.36
1½	6	35	5.8	36	200	355	1160	2060	4.66	38	210	345	1220	2000	4.66	40	225	335	1305	1945	4.66
2	6	33	5.5	33	200	400	1100	2200	4.91	35	210	390	1155	2145	4.91	37	220	380	1210	2090	4.91
¾	6½	38	5.9	46	245	288	1445	1700	4.58	48	255	280	1505	1650	4.58	50	265	265	1560	1560	4.58
1	6½	37	5.7	41	230	330	1310	1880	4.74	43	240	320	1370	1825	4.74	45	250	310	1425	1765	4.74
1½	6½	35	5.4	37	225	380	1215	2050	5.00	39	235	370	1270	2000	5.00	41	250	355	1350	1920	5.00
2	6½	33	5.1	34	225	430	1150	2195	5.30	36	235	415	1200	2120	5.30	38	250	405	1275	2065	5.30
¾	7	38	5.4	47	280	315	1510	1700	5.00	49	290	305	1565	1650	5.00	51	300	290	1620	1565	5.00
1	7	37	5.3	42	255	355	1350	1880	5.10	44	270	340	1430	1800	5.10	46	280	330	1485	1750	5.10
1½	7	35	5.0	38	250	410	1250	2050	5.40	40	265	395	1325	1975	5.40	42	270	385	1350	1925	5.40
2	7	33	4.7	35	250	465	1175	2185	5.75	37	265	450	1245	2120	5.75	39	280	435	1315	2045	5.75
¾	7½	38	5.1	48	300	330	1530	1680	5.30	50	315	315	1605	1605	5.30	52	330	300	1685	1530	5.30
1	7½	37	4.9	43	285	380	1400	1860	5.51	45	300	365	1470	1790	5.51	47	310	355	1520	1740	5.51
1½	7½	35	4.7	39	275	430	1290	2020	5.75	41	290	415	1365	1950	5.75	43	305	400	1435	1880	5.75
2	7½	33	4.4	36	275	495	1210	2180	6.14	38	290	480	1275	2110	6.14	40	305	465	1340	2045	6.14
¾	8	38	4.8	49	330	345	1585	1655	5.63	51	345	330	1660	1585	5.63	53	360	315	1730	1510	5.63
1	8	37	4.6	44	315	400	1450	1840	5.87	46	330	385	1520	1770	5.87	48	345	370	1590	1700	5.87
1½	8	35	4.4	40	305	455	1340	2000	6.14	42	320	440	1410	1935	6.14	44	335	425	1475	1870	6.14
2	8	33	4.1	37	310	525	1270	2150	6.59	39	325	510	1330	2090	6.59	41	340	490	1395	2010	6.59

Table XVI. Suggested Trial Mixes for Portland Cement Concrete With 3-inch Slump (Saturated-Surface-Dry Condition)

which is up to ¾ gallon for 100 pounds. Coarse aggregate usually contains not more than 2 percent surface moisture, which is about ¼ gallon for 100 pounds. Excess moisture in both fine and coarse aggregate could change the water-cement ratio from 6 gallons per sack of cement to 8½ gallons per sack unless a correction is applied. Such an increase would reduce 28-day flexural strength almost 20 percent. Surface moisture content, however, is based on saturated-surface-dry weight instead of a dry weight as in soils. The formula for determining amount of moisture is—

$$M=\frac{(\mathrm{SMC})}{100}\times \mathrm{Assd} \qquad (12\text{–}1)$$

$$A_w=\mathrm{Assd}+M \qquad (12\text{–}2)$$

$$W_A=W_D-0.12M \qquad (12\text{–}3)$$

where: M = Surface (excess) moisture in pounds
SMC = Surface moisture content in percent
Assd = Weight of saturated-surface-dry aggregate, (design weight) in pounds
A_w = Weight of wet aggregate required in pounds
W_A = Adjusted volume of water in gallons
W_D = Design volume of water in gallons

Example: SMC of fine aggregate = 4 percent
SMC of coarse aggregate = 1 percent

Solution:

(1) Fine aggregate

$$M=\frac{4}{100}\times 1{,}100=44 \text{ pounds of water}$$

$A_w = 1{,}100+44=1{,}144$ pounds of fine aggregate

(2) Coarse aggregate

$$M=\frac{1}{100}\times 2{,}200=22 \text{ pounds of water}$$

$A_w = 2{,}200+22=2{,}222$ pounds of coarse aggregate

(3) Water

$$W_A=33-0.12\,(44+22)$$
$$=33-8=25 \text{ gallons of water}$$

Thus, the corrected mix for a cubic yard is 5.5 sacks of cement, 1,144 pounds of sand, 2,222 pounds of gravel, and 25 gallons of water.

226. Adjustment for Entrained Air

a. A method of adjusting for air entrainment is by strength correction. An additional feature is a resulting slump reduction which keeps the ease of workability relatively constant. Water is decreased ¼ gallon and sand is decreased 10 pounds per sack of cement for each percent of air. Sand is decreased due to oversanding caused by the air bubbles.

Example: Adjust the mix given in paragraph 223 for 4 percent air content.

Solution: Cement = 5.5 sacks (no change)
Sand = $1{,}100-(5.5\times 10\times 4)=$ 880 pounds
Gravel = 2,200 pounds (no change)
Water = $33-(5.5\times \frac{1}{4}\times 4)=27.5$ gallons (adjustment to the nearest ½ gallon is adequate)

b. The yield of the mix is changed by the entrained air. The method of determining the adjusted yield consists of dividing the design yield by 1, minus the percent of entrained air in decimal form.

$$\text{Adjusted entrained air yield}=\frac{\text{design yield}}{1\ \dfrac{\text{percent air}}{100}} \qquad (12\text{–}4)$$

Example: Determine the yield of the mix design in paragraph 223 if the entrained air is 4 percent.

Solution: Design yields = 1.0 cu yd

$$\text{Adjusted air-entrained yield}=\frac{1.0}{1-4/100}=\frac{1.0}{0.96}=1.04 \text{ cu yd}$$

Section III. TRIAL BATCH METHOD

227. Introduction

The trial batch method of mix design is a simple field method of design based on experience. The trial batch method is more reliable than the book method because the trial batch can be adjusted until the mix is satisfactory. Data on design of the mix should be recorded as described in TM 5-530 for use in final mix design. Yield is then calculated for the book method or trial batch method from absolute volume of the materials (para. 231).

228. Selecting Water-Cement Ratio

The procedure for selecting the water-cement ratio described in paragraph 218 is applicable to the trial batch method of mix design. The water-cement ratio also may be selected on a trial basis or by experience.

229. Selecting Workability

Selection of the workability of the mix is discussed in paragraph 221. In the absence of established slump criteria, which is usually specified in the project specifications, the mix should be as stiff as possible and, at the same time, maintain a homogeneous voidless mass. For pavement, the mix is usually quite stiff.

230. Mixing a Trial Batch

Trial batches may be as large as the size of the mixer, but smaller quantities are more convenient (one-tenth sack batches may be used). If the water-cement ratio is 5 gallons per sack, then 0.5 gallons of water and $\frac{1}{10}$ sack of cement (9.4 lbs.) would be used. The cement and water are mixed to form a paste. Sand and gravel are then mixed with the paste until the desired consistency is obtained. Both the fine and coarse aggregate should be in a saturated-surface-dry condition. The weights of the sand and gravel used in the batch are obtained by weighing each container filled with aggregate before the trial batch is run and by weighing the container with the remainder of the aggregate after the run. The difference in weight is the weight of the aggregate used in the trial batch. Consistency of the trial batch is tested with the slump test described in TM 5–530. When the weights for the sand, gravel, and water required for one-tenth sack of cement have been determined, the weight of each ingredient required for 1 sack is obtained by multiplying by 10.

231. Calculating Yield

To calculate the amount of concrete obtained from a one-sack batch, the weights of the ingredients are converted to absolute volumes. The sum of the absolute volumes is the volume of concrete obtained from a one-sack batch, or yield. An example calculation of a theoretical yield is shown in paragraph 233*e*. In calculating the absolute volumes of the ingredients of the mix, the specific gravity of the materials is required. Portland cement normally has a specific gravity of 3.15. Specific gravities of the sand and gravel used are determined by standard tests described in TM 5–530.

232. Cement Factor

a. To determine the quantity of each ingredient necessary to batch a mixer or to estimate the total amount of each material required, the cement factor (CF) must be established. The cement factor is obtained by dividing the capacity of the mixer or job (volume) in cubic feet by the yield in cubic feet. For example, to determine the amount of each ingredient required to batch a 16S mixer, the cement factor will be equal to the capacity of the mixer divided by the yield. Capacity of the 16S mixer is 16 cubic feet with no overload; yield is assumed to be 4 cubic feet.

$$\text{Then CF} = \frac{\text{Volume (mixer capacity)}}{\text{Yield (in cubic feet)}} \qquad (12\text{–}5)$$

$$\text{CF} = \frac{16}{4} = 4$$

b. With this method, total requirements for cement, water, sand, and gravel for any project can be obtained by multiplying the appropriate cement factor by one-sack batch quantities.

233. Application of Trial Batch Method

The following example illustrates the trial batch method of mix design and calculation of yield. The Chapman flask test for specific gravity of sand and the pycnometer test for specific gravity of gravel are described in TM 5–530. The suspension method for determining specific gravity of coarse aggregate is also discussed in TM 5–530.

Example: A concrete mix is to be designed for a 10-inch concrete pavement with a flexural strength of 550 psi at 28 days, using Type I cement. The pavement will be located in an area with a severe climate. A standard 34E paver is to be used for mixing. (Capacity of the 34E paver is 34 cubic feet). Specific gravities are assumed to be 3.15 for cement, 2.65 for sand, and 2.66 for gravel.

Procedure:

a. *Water-Cement Ratio*.

(1) From figure 69, the water-cement ratio for the specified flexural strength of 550 psi for Type I portland cement at 28 days is 6¼ gallons per sack.

(2) For a 10-inch paving slab to be placed in a severe climate, the water-cement ratio for durability selected from table XV is 5½ gallons per sack.

(3) The lowest water-cement ratio that will satisfy requirements for both flexural strength and durability is 5½ gallons per sack.

b. *Slump*. Required slump is between 1½ and 2 inches.

c. Proportions. The cement and water are mixed together and sand and gravel are added to the paste until a well-proportioned plastic mix with a 1½-inch to 2-inch slump is obtained. (For the initial trial batch, one part of sand and two parts of aggregate may be used.) More than one trial mix may be necessary to obtain the required slump, but a slight variation from the slump is not detrimental as long as the mix is sufficiently plastic to be finished without excess mortar. Slump in excess of requirements can be corrected by adding more aggregate.

d. Computing Requirements. Assuming that the trial mix for $\frac{1}{10}$ sack of cement is 9.4 pounds of cement, 0.55 gallons of water, 18.3 pounds of sand, and 36.2 pounds of gravel, quantities for a one-sack batch are obtained by multiplying by 10. Quantities for a one-sack batch are—

94 pounds of cement
5½ gallons of water
183 pounds of sand
362 pounds of gravel

e. Yield. To determine the yield of this mix, the absolute volume of each component is computed from the following formula:

$$\text{Absolute volume} - \frac{\text{Saturated-surface-dry weight of material}}{\text{Specific gravity} \times \text{unit weight of water}} \qquad (12\text{–}6)$$

$$\text{Cement} = \frac{94 \text{ lb}}{3.15 \times 62.4} = 0.478 \text{ cu ft}$$

$$\text{Water} = \frac{5.5 \text{ gal}}{7.5 \text{ gal per cu ft}} = .73 \text{ cu ft}$$

$$\text{Sand} = \frac{183 \text{ lb}}{2.65 \times 62.4} = 1.107 \text{ cu ft}$$

$$\text{Gravel} = \frac{362 \text{ lb}}{2.66 \times 62.4} = 2.181 \text{ cu ft}$$

$$\text{Yield} = \quad = 4.500 \text{ cu ft, or } 4.5 \text{ cu ft}$$

f. Cement Factor. To obtain the cement factor for a 34E paver, the capacity of the paver is divided by the yield:

$$\frac{34}{4.5} = 7.56$$

g. Batching Requirements. When sacked cement is used, whole sack increments are preferable. With a cement factor of 7.56, it is necessary to reduce the CF to 7, as 7×4.5=31.5 cu ft (8×4.5=36 cu ft). The rated capacity of a 34E paver is 34 cu ft with an overload capacity of 10 percent. However, the rated capacity will not be exceeded unless properly authorized. Final proportions for charging the 34E paver are—

	For sacked cement	*For bulk cement*
Cement	7 × 94 = 7 sacks or 658 lbs	7.56 × 94 = 710.64 lbs
Water	7 × 5.5 = 38.5 gal	7.56 × 5.5 = 41.58 gal
Sand	7 × 183 = 1,281 lbs	7.56 × 183 = 1,383.48 lbs
Gravel	7 × 362 = 2,534 lbs	7.56 × 362 = 2,736.72 lbs

h. Trial Batch Criteria.

(1) Sand and gravel used in trial batches should be in a saturated-surface-dry condition and correction for surface moisture should be made at the mixer as outlined in paragraph 225.

(2) If a mixer is used instead of the 34E paver, the factor for the capacity of the mixer can be found in the same manner, starting with a one-sack batch and using a cement factor.

(3) For estimating materials for large jobs, a handling loss factor of 5 percent to 10 percent should be added after the material requirements have been calculated. Additional loss factors may be necessary for extensive projects.

CHAPTER 13

CONCRETE EQUIPMENT

Section I. STANDARD EQUIPMENT

234. Introduction

Standard concrete construction equipment includes concrete mixers, pavers, spreaders, finishers, steel forms, and auxiliary equipment, such as hoppers, vibrators, and wheelbarrows. A discussion of the major items of standard concrete equipment follows in the succeeding paragraphs of this section. Handtools used for finishing concrete, such as trowels, edgers, floats, and brooms, are listed in SM 5-4-5180-S19. Use of equipment and productive capacities are discussed in TM 5-331. DA Pam 310-4 should be consulted for references on operation. Items are procured separately through the applicable supply manual.

235. Form Riding Subgrader

a. Description. The form riding subgrader (fig. 70) is a self-propelled form riding machine that mechanically removes excess subgrade material between the forms, prior to the placing of concrete. It is a rugged, precision machine that assures accurate control of slab thickness.

b. Operation. Subgrade material should always be slightly higher than necessary between the forms. The subgrader, therefore, is constantly cutting and removing material across its entire face. If excess subgrade is not placed, low spots will require filling. These fill areas are difficult to compact to an equal density with the surrounding area. Spot changes in

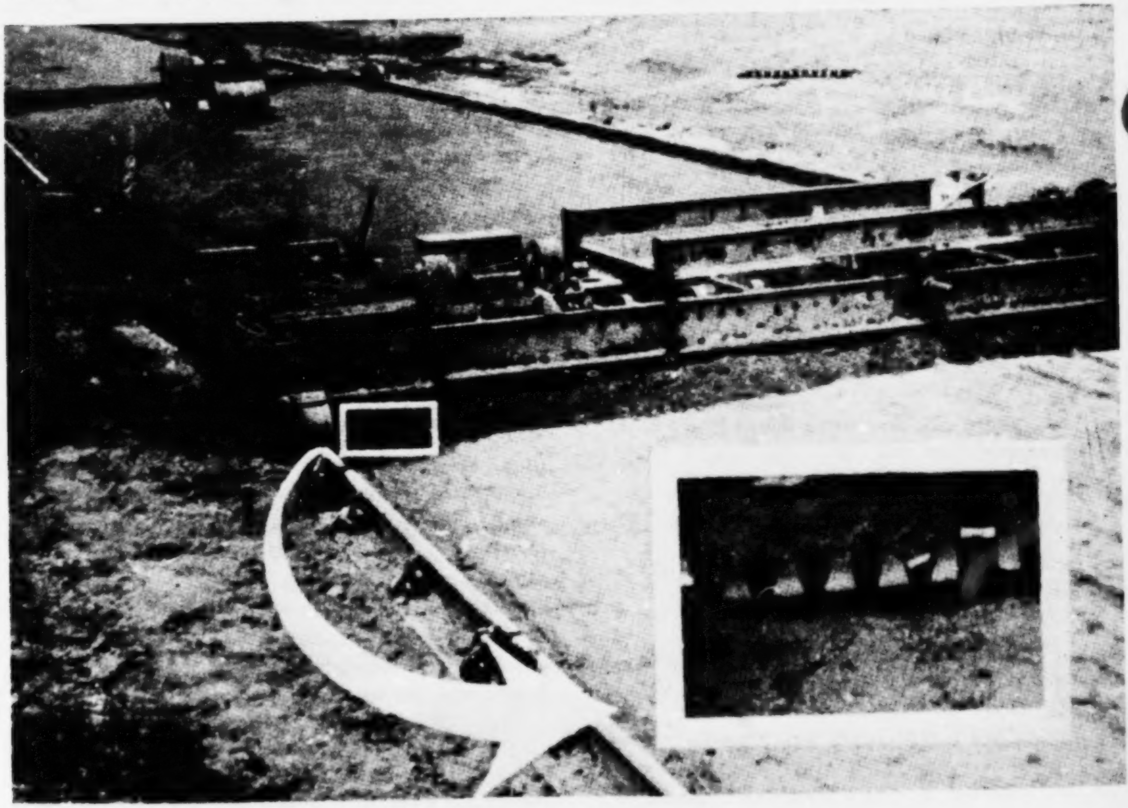


Figure 70. Form riding subgrader.

density will cause early failure due to fatigue in the pavement.

236. Aggregate Batching Plant

a. Description. The 100–TPH aggregate batching plant (fig. 71) rapidly and accurately proportions three aggregates by weight. The plant consists of three compartments, with a total capacity of 66 cubc yards, a batching hopper, a scale unit, and four supporting legs.

b. Operation. The material in each compartment of the bin unit is discharged separately through clamshell type doors into the batching hopper. The batcher and scale unit consists of a single compartment steel weigh box with a capacity of 62 cubic feet (66 cubic yard batching plant) and a beam box with a springless indicator. The beam box is equipped with three scale beams, one for each of the three aggregates normally used for concrete. This permits independent weighing of each material according to the poise setting on the respective beams. The top beam is called the master beam and the two lower beams are called auxiliary beams. Each beam has two poises, a major and minor poise. On the master beam, the major poise is movable through a range of 3,000 to 6,000 pounds, depending upon the make and model, in 100-pound increments; the minor poise is movable through a range of 100 pounds in increments of 2 pounds, or a total weighing capability of 3,100 pounds. The two auxiliary beams have the same weight divisions. The master beam is the only beam that is connected to the scale indicator, and thus must come to balance with each weighing operation. The auxiliary beams are locked in and out of play by the use of two trig locks, one for each beam. When the auxiliary beams are locked out, the master beam rides free; when they are in operation, they are tied to the master beam by a ladder. The scale indicator is of the oil damper type. The oil damper consists of a dashpot that is partially filled with a light machine oil. A plunger, inside the dashpot and connected to the indicator, moves in this oil to dampen or slow down the free swinging action of the indicator needle, thus bringing the indicator quickly to balance. Once the material is weighed, the bottom gate of the hopper is opened, dropping contents in the bed of a truck waiting below.

c. Capacity. This plant is rated at 100–TPH. This will vary somewhat with the experience of the operators, the method of reloading the hoppers, and the number of aggregates being batched. An efficient crew can support two 34E pavers or four 16S mixers for most paving operations.

237. Cement Batching Plant

The standard cement batching plant (fig. 72) is the 200-barrel model. This unit is usually square and has a general appearance similar to that of the aggregate batching plant. The function of this plant is to proportion the amount of cement being used per batch of concrete. It is mounted on four columns with the single bin unit suspended between them. Below the bin unit is a scaled batcher unit. The batcher is equipped with a flexible hose through which the cement is dropped into the batch truck. A single beam scale is provided to weigh the material. An air compressor supplies a constant flow of air to the cement in the bin unit to prevent the cement from consolidating. The bin is loaded by an inclosed gasoline engine driven elevator capable of handling 50–75 TPH. The cement is taken in through a hopper and picked up by a screw conveyor which transports the bulk cement to the elevator. TM 5–3895–210–12 contains additional information on the cement batching plant.

238. Concrete Mixer, 16S

a. The 16S concrete mixer (fig. 73) is a self-contained unit capable of producing 16 cubic feet of concrete plus a 10 percent overload per batch. The hourly production capacity will vary between 10- and 15-cubic yards depending on the efficiency of the personnel. Aggregate larger than 3 inches will damage the mixer. The mixer consists of a frame which is equipped with wheels and towing tongue for easy movement, an engine, a power loader skip, mixing drum, water tank, and auxiliary water pump. The mixer may be used as a central mixing plant. The most economical central plant arrangement is discussed in paragraphs 258 and 259. Many makes and models are currently available through supply channels. Additional information is contained in TM 5–1131, TM 5–1143, TM 5–1555, TM 5–3895–205–10, TM 5–3895–219–10, and TM 5–3895–221–15.

b. Some 16-cubic foot capacity mixers are designated 16SM. This designation means that they are also capable of mixing mortar and has nothing to do with their capability of producing a paving mix.

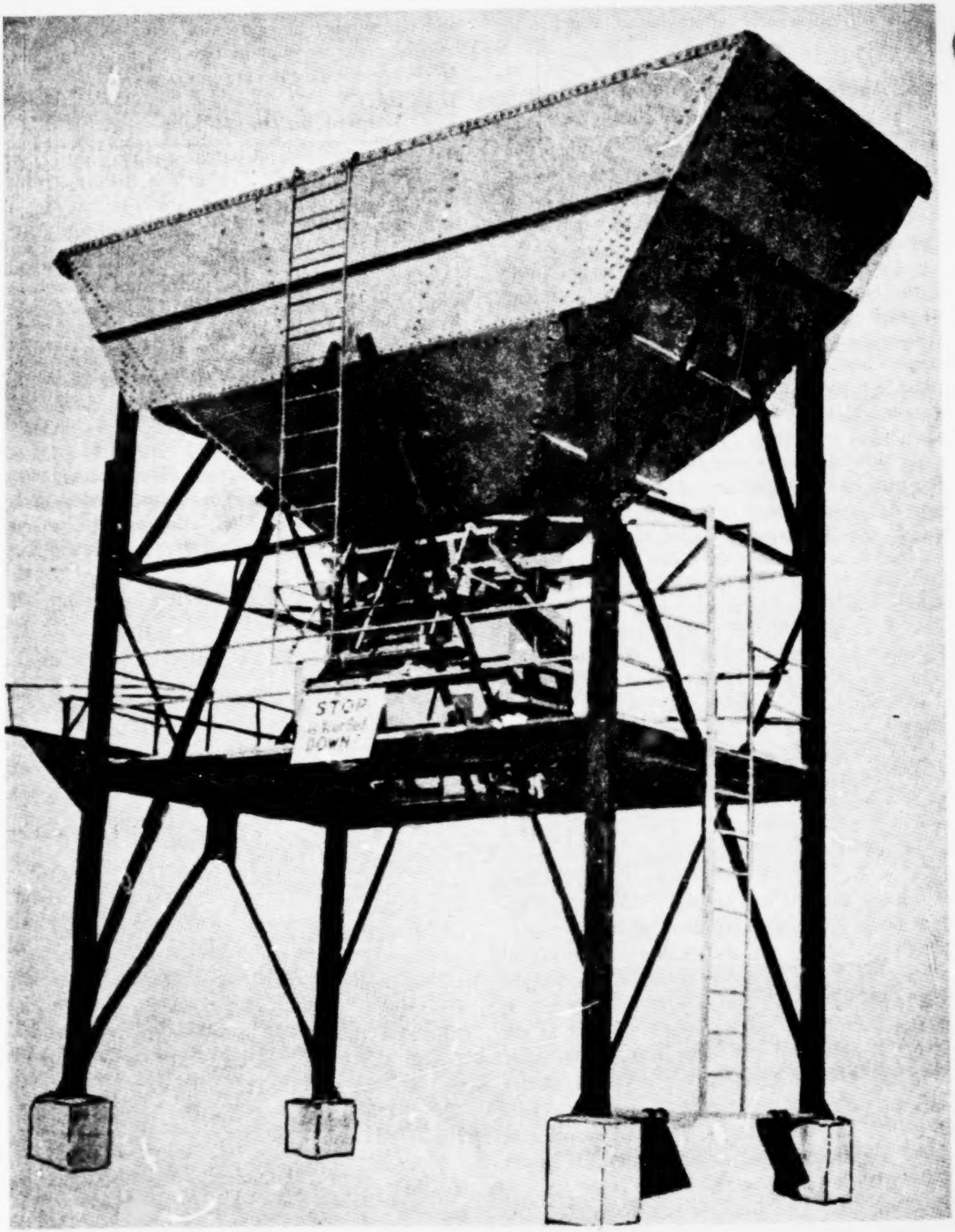


Figure 71. Aggregate batching plant.

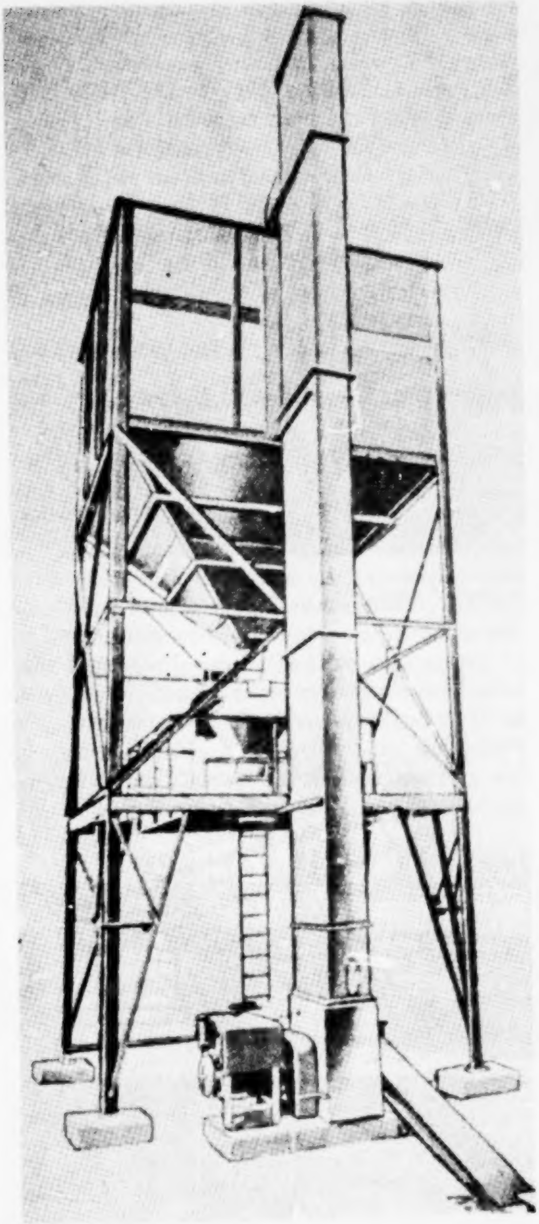


Figure 72. Cement batching plant.

239. Dual Drum Concrete Paver, 34E

a. The 34E dual drum paver (fig. 74) has a rated capacity of 34 cubic feet per batch. The maximum hourly production will depend upon the skill of operating personnel and the rapidity of loading. The paver is mounted on crawlers. All turns should be gradual as damage will occur on sharp turns due to the absence of idler sprocket recoil springs to absorb the additional track tension.

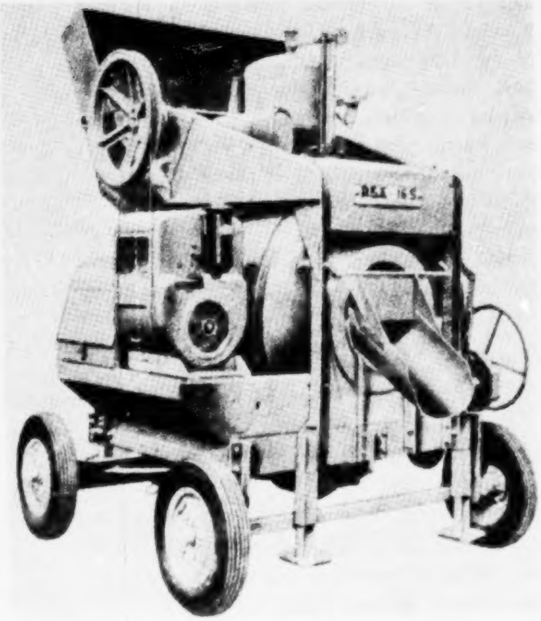


Figure 73. 16S concrete mixer.

b. Cement and aggregates are dumped into the first drum by the skip. Water and liquid admixtures are added from separate tanks. After the constituents are partially mixed, they are transferred to the second drum. The first drum is recharged while the second drum is completing the mixing of the first batch. The batch is discharged into a boom supported 55-cubic foot concrete bucket. The bucket travels along the boom. The boom pivots in a semicircle allowing the bucket contents to be placed anywhere within a 31.5-foot radius. The bucket doors may be partially opened while the bucket is moving, allowing the concrete to spread over a desired area. Additional information concerning the 34E paver may be found in TM 5-7071 and TM 5-3895-202-10.

240. Concrete Spreader

a. The concrete spreader (fig. 75) is a self-propelled form riding device that distributes the intermittent concrete batches from the paver. It is most efficient when two 34E pavers or eight 16S mixers (eight mixers are necessary due to placement time, not hourly capacity) are producing the concrete.

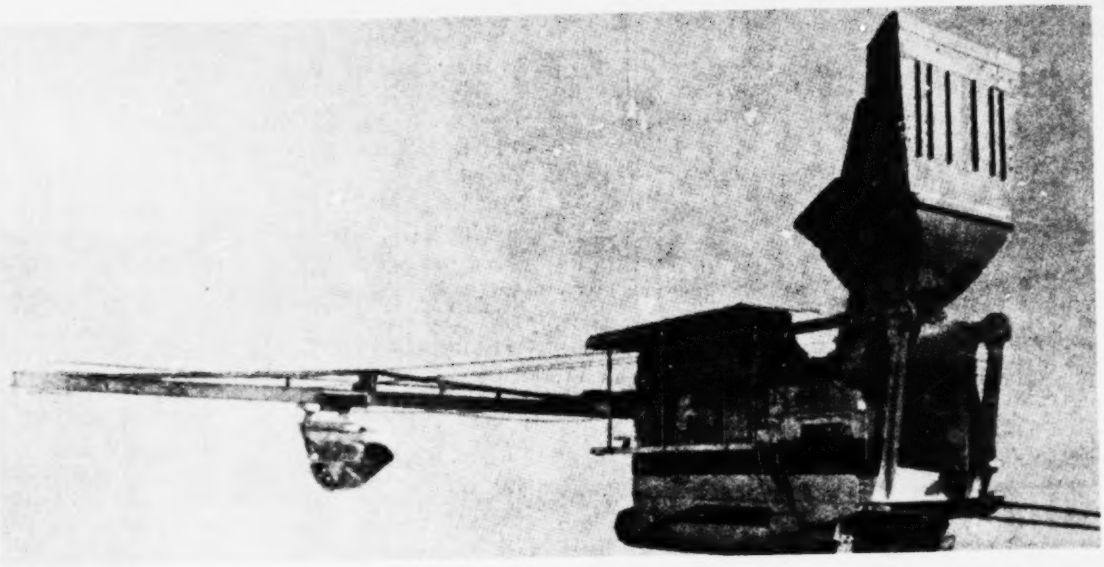


Figure 74. 34E dual drum concrete paver.

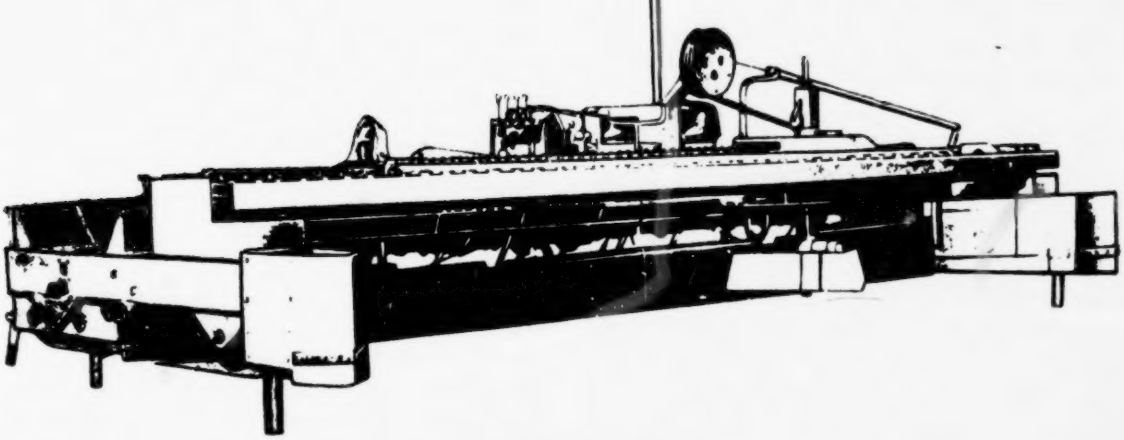


Figure 75. Concrete spreader.

The form width cannot vary more than 0.1 foot. A greater variation will allow the unit to drop off one side of the form. The wheels are designed so that the spreader can operate between forms, between two completed parallel slabs, or between a completed slab and a parallel line of forms.

b. The moving spreading ("V" spreader) blade can be adjusted to spread at, above, or below the form level. This permits the laying of welded wire fabric between two lifts of concrete. Behind the spreading blade is the strike off plate which may be adjusted for a crown, warp, or straight cross section, in addition to the same height adjustment as the "V" spreader.

c. The pan type vibrator on the spreader is effective to a depth of 12 inches. The internal vibrators will consolidate an area approximately 36 inches in diameter. Only one type vibrator can be used at once. Caution must be taken when vibrating an air-entrained mix. Overvibration can cause a loss of entrained air, although some vibration is necessary. TM 5-3895-236-12 is an additional source of information on the concrete spreader.

241. Pneumatic Concrete Vibrator

The pneumatic vibrator (fig. 76) is found as TOE equipment in some units and also as a Class IV item. The unit is available in two sizes, determined from the length and diameter of the tube. The smallest is 17¾ inches long with a 2½-inch diameter and the largest is 21⅝ inches long with a 3-inch diameter. The power unit for both units is a five-lane rotary air motor. A flexible, bonded, rubber coupling between the air motor and the unbalanced rotor serves to eliminate transmission of shock loads between these rotating parts. Radial ball bearings at each end of the unbalanced rotor carry the rotating load and are designed to facilitate proper assembly of the vibrator. A specially carbonized and hardened steel casing tube resists the outside wear. The tip is covered with a long wearing stellite material. The unit operates on 80 psi and produces 8,500 to 9,000 vibrations per minute. The smaller unit should be used on concrete with a slump over 3 inches and the larger on concrete with a slump under 3 inches.

242. Transverse Concrete Finisher

a. The transverse concrete finisher (fig. 77) is a self-propelled form riding unit that follows the spreader, finishing the concrete to the desired cross section. The finisher screeds can be adjusted so that the bottom plate strikes the concrete at an angle in addition to being capable of all of the adjustments of the spreader. The tilt adjustment of the bottom plate is necessary for extra stiff mixes.

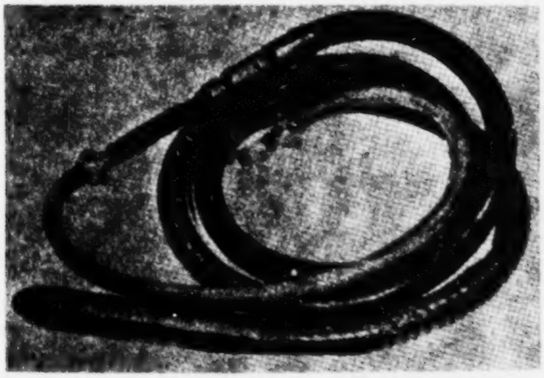


Figure 76. Pneumatic concrete vibrator.

b. The finisher has a front and rear screed and may have a pan vibrator in the middle. The remainder of the machine exists entirely to operate the screeds. The pan vibrator will effectively consolidate concrete to a depth of 12 inches. The vibrator should not be used if the vibrator on the spreader is being used. The screeds work at right angles to the centerline, thus any form irregularities will be reflected in the finished concrete. TM 5-3895-216-10 may be consulted for additional information.

243. Concrete Finishing Bridge

Two types of bridges are available through supply channels. Both are adjustable from 20 to 25 feet. One type consists of two end truck assemblies and two planks anchored to them (fig. 78). Take up bolts to apply tension are provided beneath the planks. These bolts can apply enough tension to permit four men to work on the bridge. Another type is mounted on a hand-powered traction carriage and consists of two bridges. This machine permits eight men to work on the bridge and not leave the machine while it is being moved. One man merely turns a hand wheel which in turn supplies power through a chain drive to the rear axle and propels the unit along the forms.

244. Curing Machines

a. Automatic Curing Machines. Automatic curing machines (fig. 79) are form riding and self-propelled. Although the machines vary with make and model, they consist of a telescoping frame that supports a deck. An engine is mounted on this deck to provide power for the traction wheels and a pump. The deck has room for approximately 1 day's supply of curing material in 55-gallon drums. The pump draws this material from the drums and forces it out through a spray assembly onto the pavement.

b. Portable Curing Machines. The portable unit is for small volume jobs and has only a 55-gallon capacity. The unit consists primarily of a pneumatic tired, hand transportable barrel carriage equipped with a gasoline powered pump. The pump supplies pressure to the material from the barrel to the spray nozzle. The spray nozzle is moved over the area to be cured in much the same manner as a person would water a lawn.

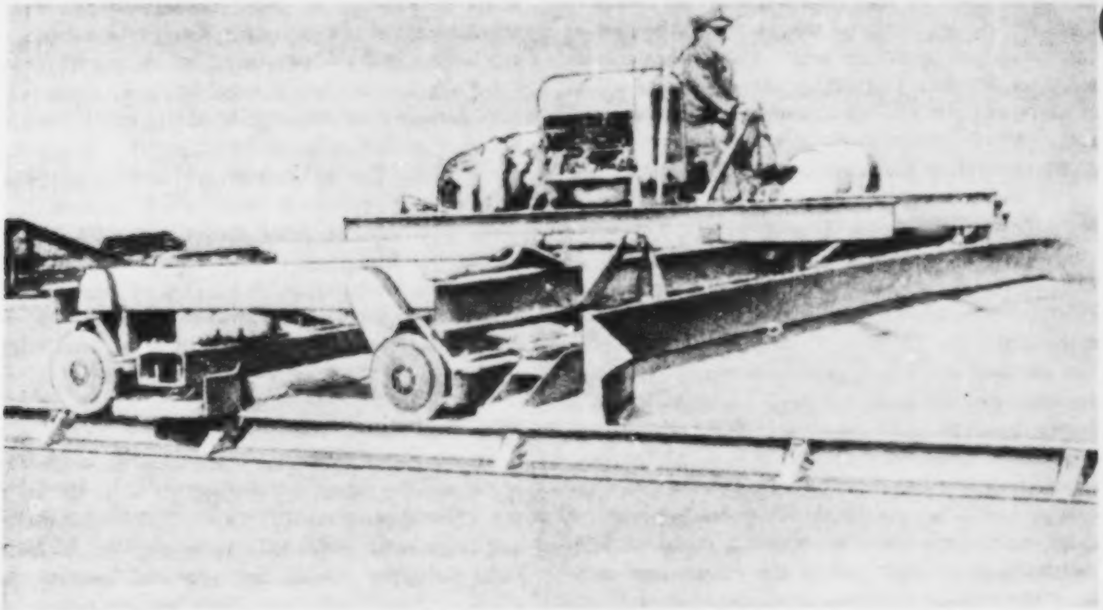


Figure 77. Transverse concrete finisher.

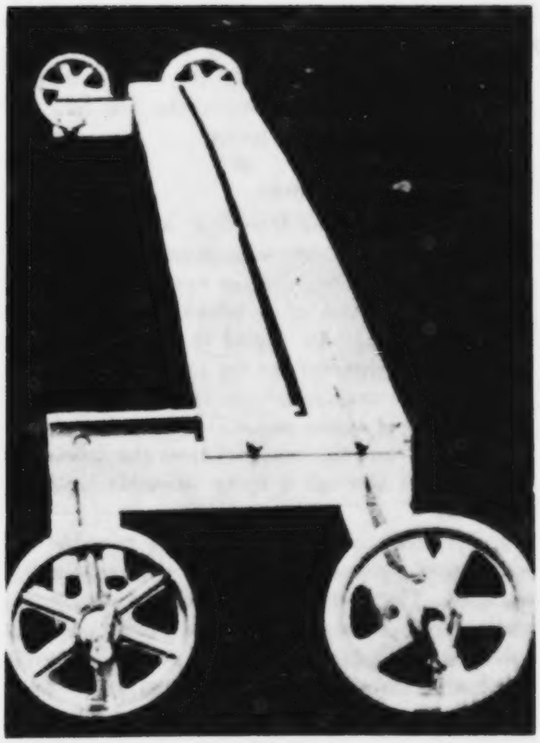


Figure 78. Concrete finishing bridge.

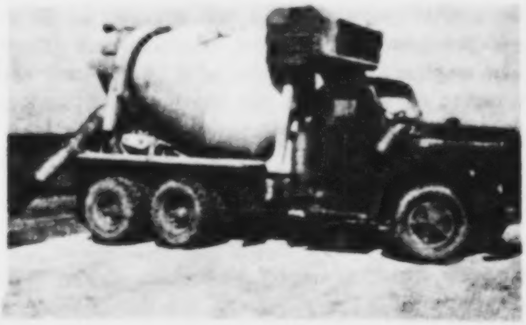


Figure 79. Automatic curing machine.

245. Concrete Saw

The concrete saw (fig. 80) is used to cut longitudinal and transverse joints in finished concrete pavements. Several types of blades are available, the most common of which have either diamond or carborundum cutting surfaces. The diamond blade is used for hard cutting and the carborundum blade for cuts after aggregate has been displaced by vibration. The unit is small and can be operated by one man. Once the cut has been started, the machine will provide its own tractive power. A water spray is used to flush the saw cuttings from the cutting area and to cool the cutting blade.

Figure 80. Concrete saw.

246. Miscellaneous Concrete Equipment

a. Steel Concrete Forms. Steel concrete forms are discussed in paragraphs 262 through 264.

b. Pin Pullers. Several types of pullers are available commercially. One type used consists of a lever and fulcrum. On the end of the lever is a head to clamp on to the head of the pin. Pressure is applied to the end of the lever and the action over the fulcrum exerts sufficient force to remove the pins. Some pin pullers are just clamps for the pin heads connected to a peavy handle. Either type is efficient and many more are fabricated at local levels.

c. Hot Water Heater (Concrete Mixer). A hot water heater is available as Class IV equipment. The heater consists of a vaporizing burner with a kerosene tank and a water tank. The unit is capable of producing 800 gallons per hour at a 100° F. temperature rise. It is used to heat water for concrete in cold weather operation. Caution should be exercised when using a hot water heater to keep the water from reaching a temperature of 175° F. If water at this temperature is added to a mix, a flash set of the concrete may occur. The use of the heater in cold weather operations is discussed in paragraph 298.

d. Concrete Buckets. Concrete buckets are available in sizes from ¾ cubic yard through 2 cubic yards as standard TOE and Class IV supplies. The buckets are normally used to place structural concrete. Most of these buckets are cylindrical in shape with a clamshell door at the bottom that can be hand operated. The construction of the bucket normally lends itself to use with a crane; however, other methods of utilization can be employed. Concrete buckets can be easily constructed in the field. Well designed expedient buckets will work better than standard buckets in transferring mix from the 5-ton dump truck to pavement forms. The scoop loader (front end loader) with a 4-in-1 bucket works very well as an expedient concrete bucket provided there is maneuvering room alongside the forms and the slab width is not too great.

247. Supporting Equipment

Cranes, finishing tools, water pumps, shovels, etc. will be necessary in concrete construction. Each job is unique and should be treated as such when planning for equipment utilization. A complete analysis of the job and its equipment requirements should be made before operations are begun. Supporting equipment should not be neglected in this analysis. Although expedients may be substituted for most pieces of supporting equipment, having the correct tool for the job will greatly improve the overall project efficiency.

Section II. NONSTANDARD EQUIPMENT

248. Introduction

Concrete equipment not currently available through normal supply channels is discussed in paragraphs 249 through 255. A brief discussion of the description and use of the equipment is included herein to familiarize personnel with some of the civilian equipment which may either become standard Army equipment or be encountered on a project employing civilian contractors.

249. 34E Triebatch Concrete Paver

A piece of concrete paving equipment developed by the Koering Company is the 34E Triebatch Concrete Paver. This paver features a single mixing drum with three compartments rather than a single drum with two compartments which is now standard to the Army. The manufacturer claims that this design will increase productive capacity up to 43 percent. The electric batchmeter, with its push-button controls, makes the work of the operator easier since it controls all of the mixing operations, including raising and lowering the skip. Also, the final discharge chute will not open until the bucket is in position to receive the next batch. If the bucket is not in position or if any operation should fail to function, all operations to the rear will become static which will prevent material from collecting in one of the three drums. The capacity per batch is the same as the 34E Dual Drum; i.e. 34 cubic feet plus 10 percent overload on up to a 6 percent grade.

250. Transit-Mixer and Agitator Trucks

a. A transit-mixer or agitator truck is a truck on which a concrete mixer is mounted (fig. 81). If the aggregate, including the cement, is charged into the mixer at a central batching plant, with mixing to be done enroute to the job, the unit is called a transit-mixer. If the unit is used to haul ready-mixed concrete, which requires agitation enroute to the project only to prevent it from segregating, the unit is called an agitator. Transit-mixers are available in sizes varying from 1 to more than 7½ cubic yards. If a unit is used as an agitator, the capacity will be considerably greater than when it is used as a transit-mixer, because the concrete is premixed, and thus, occupies a volume less than that of the aggregates measured separately.

b. When concrete is delivered by transit-mixer or agitator trucks, the effect of mixing concrete for long periods may be questioned. Tests that have been conducted over periods of several hours indicate that when concrete is mixed for a long time, the slump will decrease and the compressive strength will increase for periods up to 2½ hours or longer. Ready-mix concrete should be discharged from the transit-mixer or agitator truck not later than 1½ hours after the introduction of the water to the cement and aggregate, or the cement to the aggregate.

251. "Dumpcrete" Trucks

"Dumpcrete" trucks (fig. 82) are a special type of truck body used to transport mixed concrete from central mixing plants to the job site. The non-agitating box looks much like a bathtub. In addition to many other uses, these trucks can be used with the Maxon spreader. "Dumpcrete" is a trade name given these truck bodies by the Maxon Equipment Company.

252. Placement Machines

a. Slipform Paver. The slipform paver is used in a relatively new method of concrete pavement placement. The unit is crawler mounted and requires no forms. A long attached form trails behind the machine. Low slump concrete is placed in a hopper and forced out through an extrusion

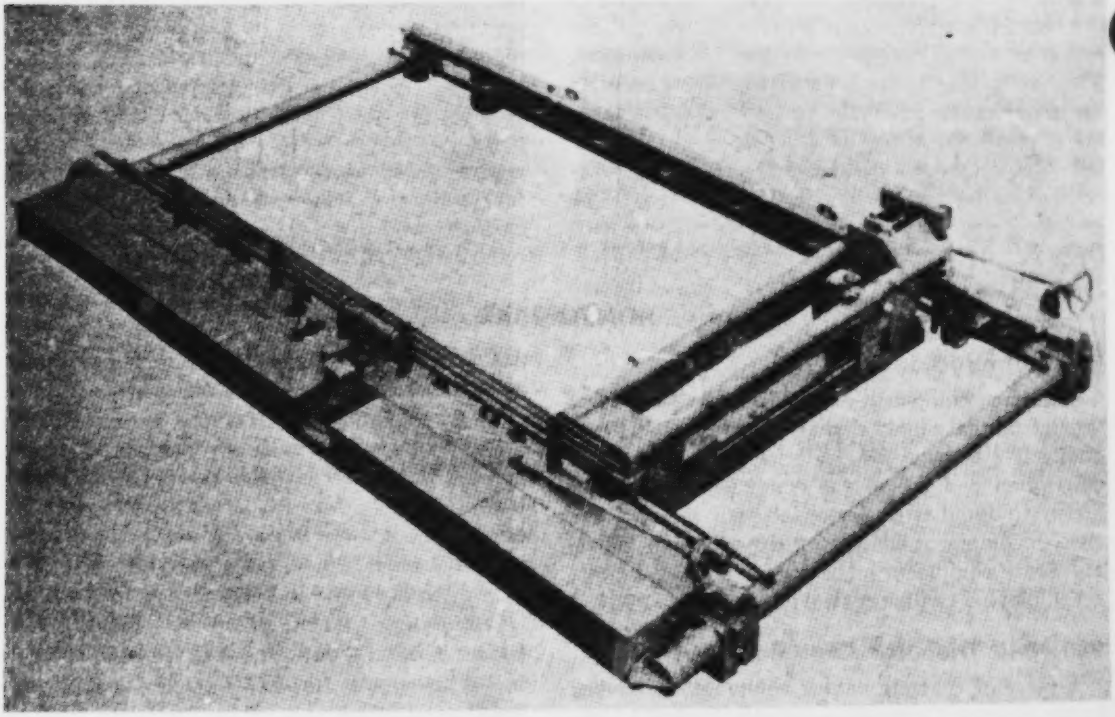


Figure 81. Transit mixer.

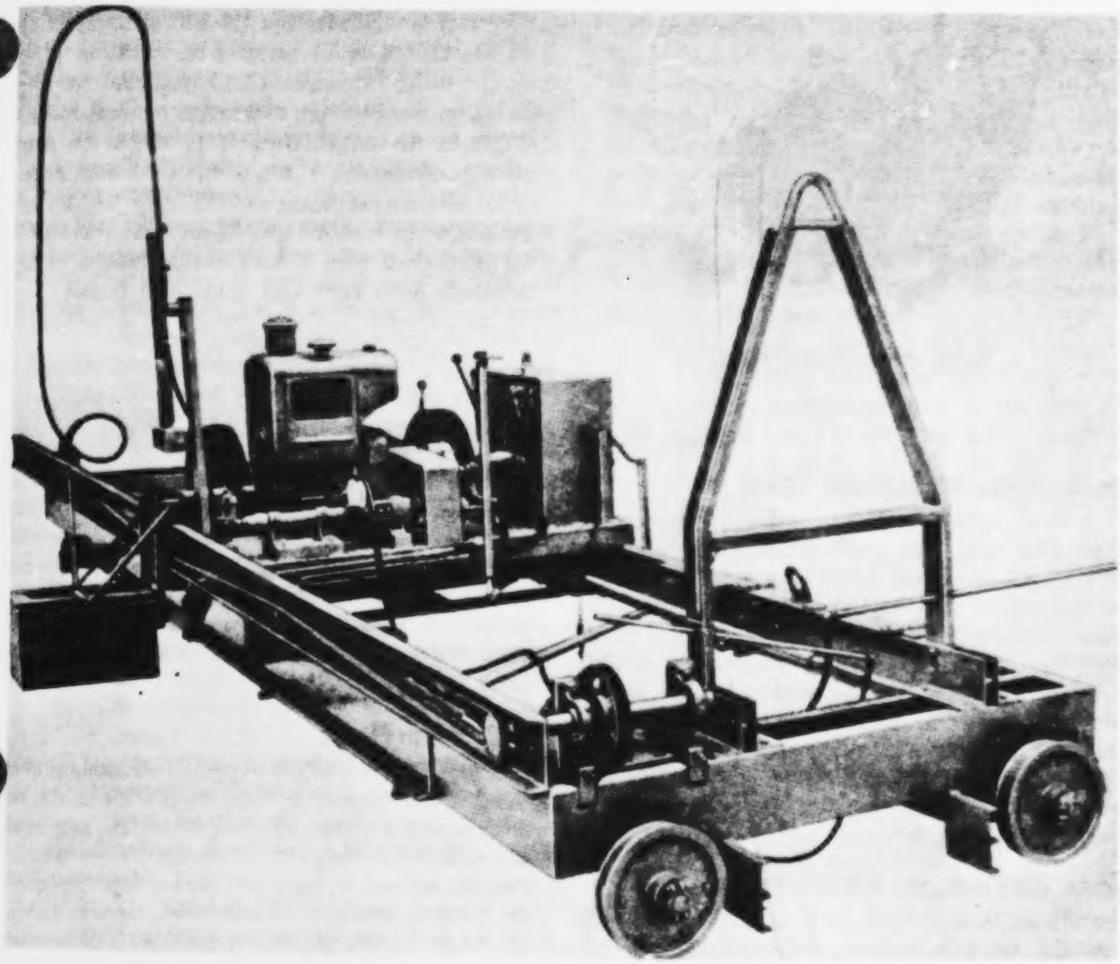


Figure 82. "Dumpcrete" truck.

assembly under a very high unit pressure. As the machine moves forward, the concrete between the trailing forms is completely finished except for minor handwork along the edges. Once the machine has moved the length of the trailing form, the concrete is no longer enclosed by the forms and needs no further support.

b. Maxon Spreader. The Maxon Spreader is another recent advancement in concrete paving. This unit is form riding and consists of a 4½-cubic yard hopper mounted on the frame and traveling back and forth between the forms. The hopper can be raised or lowered to spread either at or below form level. A pan type vibrator can be attached to the rear of the machine. This unit normally is used on high production jobs where concrete is being produced in a central plant and being hauled to the spreader in trucks.

253. Longitudinal Finisher

The longitudinal finisher (fig. 83) is a form riding piece of equipment which provides the final machine finish to the concrete pavement. The finish is applied by the longitudinal reciprocating motion of the screed across the slab plus the forward motion of the entire finisher. Crown contours are controlled by adjustment of the templates on which the screed carriage travels. Contour set on the templates is duplicated on the slab surface by th screed. Templates are adjusted by adjusting screw set at 24-inch intervals. This adjustment can produce a maximum crown of 3 inches on most models. Width of the screed plate is 12 inches on some models. Changes in width, within the 4-foot differential between maximum and minimum width slabs finished by each model, can be made by repositioning the wheels with a hand crank. Speeds of the operating units vary with make and model.

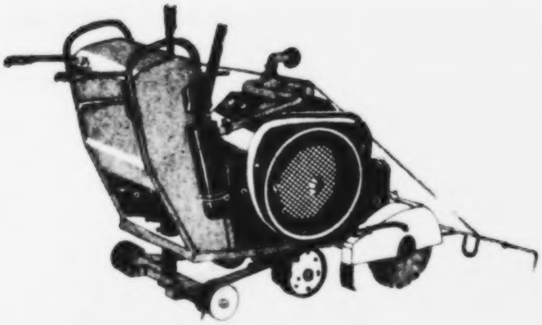


Figure 83. Longitudinal finisher.

Section III. CONCRETE PLANTS

254. Types of Concrete Plants

Concrete plants cannot be classified rigidly as to use, size, or by any other arbitrary classification. There are single use units both large and small, multipurpose units also large and small, portable, semiportable, and fixed installations. Many plants overlap specific groupings. Therefore, the classification of a plant will depend, to a great extent, upon its use. For purposes of discussion in this manual, concrete plants will be broken down into four categories: Portable on-the-job plants, highway and airfield construction plants, batch plants, and central mix plants.

255. Portable On-the-Job Plants

The standard portable on-the-job plant is the 16S concrete mixer discussed in paragraph 238 (fig. 73). The concrete mixer is a self-contained unit capable of producing 16 cubic feet of concrete plus a 10 percent overload. The plant can be used for maintenance and repair of concrete roads or airfields, but is not normally used in the initial construction phase, except as a component unit of an expedient central mixing plant (para 260).

256. Highway and Airfield Construction Plants

The major piece of equipment used in the highway and airfield construction plant is the 34E dual drum concrete paver (fig. 74). The 34E paver is a self-propelled, crawler-mounted unit with a 36-foot boom which supports a bucket for distribution of the concrete mix. The boom swings right or left in a 160° arc and can be raised or lowered as desired to distribute the concrete between the pavement forms. It is the key to concrete operations for highway and airfield construction and determines the size of proportioning and the number of material handling equipment needed for the construction operation. The aggregates, cement, and water are mixed in the paver, but the proportioning of the cement and aggregates is accomplished by a batch plant and hauled to the paver on the construction site.

257. Batch Plants

a. Types. There are two types of batching plant These are the aggregate batching plant and the cement batching plant. The purpose of the aggregate and cement batching plants is to accurately proportion the amount of aggregate and cement required per batch of concrete. The standard cement batching plant is the 200-barrel model. The cement plant has a general appearance similar to that of the aggregate batching plant. The 105-ton, 66-cubic yard aggregate batching plant is capable of feeding one 34E dual drum paver or two 34E single drum pavers.

b. Location Considerations. Both plants are normally located in proximity to each other, depending on local conditions or circumstances. The batch plant may be located at either the job construction site or at the source of aggregate. A hillside location will permit gravity handling of materials with a minimum of new construction and may eliminate cranes or conveyors. Considerations for the overall selection of a site location are—

(1) To handle the large volume of material, the batching plant site should have ample area, and be laid out to insure a free flow of vehicular traffic.

(2) The drainage pattern of the surrounding area must be carefully studied so that in the event of inclement weather, the area does not become pitted or rutted and thereby slow down the movement of vehicular traffic or contaminate aggregate stockpiles.

(3) Methods or equipment available to charge the plant will also have a bearing on site selection. If a crane is used, it must be located so that it is accessible to both the aggregate stockpiles and the bin unit of the aggregate batch plant.

(4) Whenever possible, the plant should be located in such a manner as to prevent the execution of backup maneuvers by trucks. A straight through drive saves valuable time which is normally lost in backup maneuvers.

(5) The truck traffic pattern should be organized so that empty trucks at no time conflict with partly or fully loaded trucks.

(6) Distance from aggregates, construction site, and the traffic pattern afforded by the existing roads will also influence site location.

(7) The initial location of aggregate, cement, and water facilities for washing the aggregate also influence site selection.

c. Advantages of Batching Plant at the Source of Aggregate.

(1) The plant has to be set up only one time.

(2) Aggregates require handling only one time.

(3) Concentration of effort (maintenance, mess, etc.) is possible.

(4) Less support equipment is needed (dozer at quarry site can help with stockpiles, crane unloading railcars can load batch plant).

d. Advantages of Locating Batch Plant at Job Site Location.

(1) Stockpiles have uniform moisture content.

(2) Since the haul distance is shorter, there is better control from plant to paver.

(3) Trucks can haul to plant during inclement weather and thereby save time otherwise lost by double handling of aggregates.

(4) Modification of fewer trucks is required because the haul distance from plant to paver is greatly reduced.

(5) Greater number of sites is available for site location.

e. Disadvantages. Generally, the advantages to the location of the plant at the source of aggregates are disadvantages to the location at the job site and vice versa.

f. Classification of Batch Plant as to the Number of Stops. Batching plants can be classified as to a one-, two-, or three-stop type. Typical layouts of the one-, two-, and three-stop plants are shown in figures 84, 85, and 86 respectively. Each of these layouts may be modified to meet available transport and equipment capabilities.

(1) In the one-stop type (fig. 84), aggregates and cement are loaded at one stop of the truck. A one-stop plant is the most efficient, but likewise, the most expensive. Belt conveyors usually are used to fill the batcher bins and often to build the stockpiles.

(2) At the two-stop plant (fig. 85), coarse aggregate and cement are loaded first (coarse aggregate on the bottom) and a blanket of sand is placed over the cement at the second stop. If three sizes of aggregates are being batched, it is difficult, if not impossible, to stockpile and batch enough material to keep two 34E dual drum pavers operating at an efficient rate. Also, the end pins may be contaminated by material dropping from a clam shell while filling the center bin.

(3) In the three-stop type (fig. 86), coarse aggregates are loaded first, cement second, and the fine aggregate at the last stop. A three-stop plant is somewhat more expensive to construct and operate than the two-stop plant, but can easily supply two 34E dual drum pavers.

g. Loading of Materials. The coarse aggregates should always be loaded first to scour out the bed of the truck when the materials are dumped into the skip of the paver. Next, the cement should be loaded; then a sand blanket is loaded last to prevent the cement from blowing away during the trip to the paver. Normally, at a one-stop batch plant operation where a bulk cement plant is not used, the cement bags are broken directly into the batch compartments of the truck. A cite for the cement should be selected where the amount of handling can be cut down or is near the paver.

h. Batch Trucks. The project supervisor has two choices in modifying the 5-ton dump truck for hauling concrete materials. Maximum use per truck

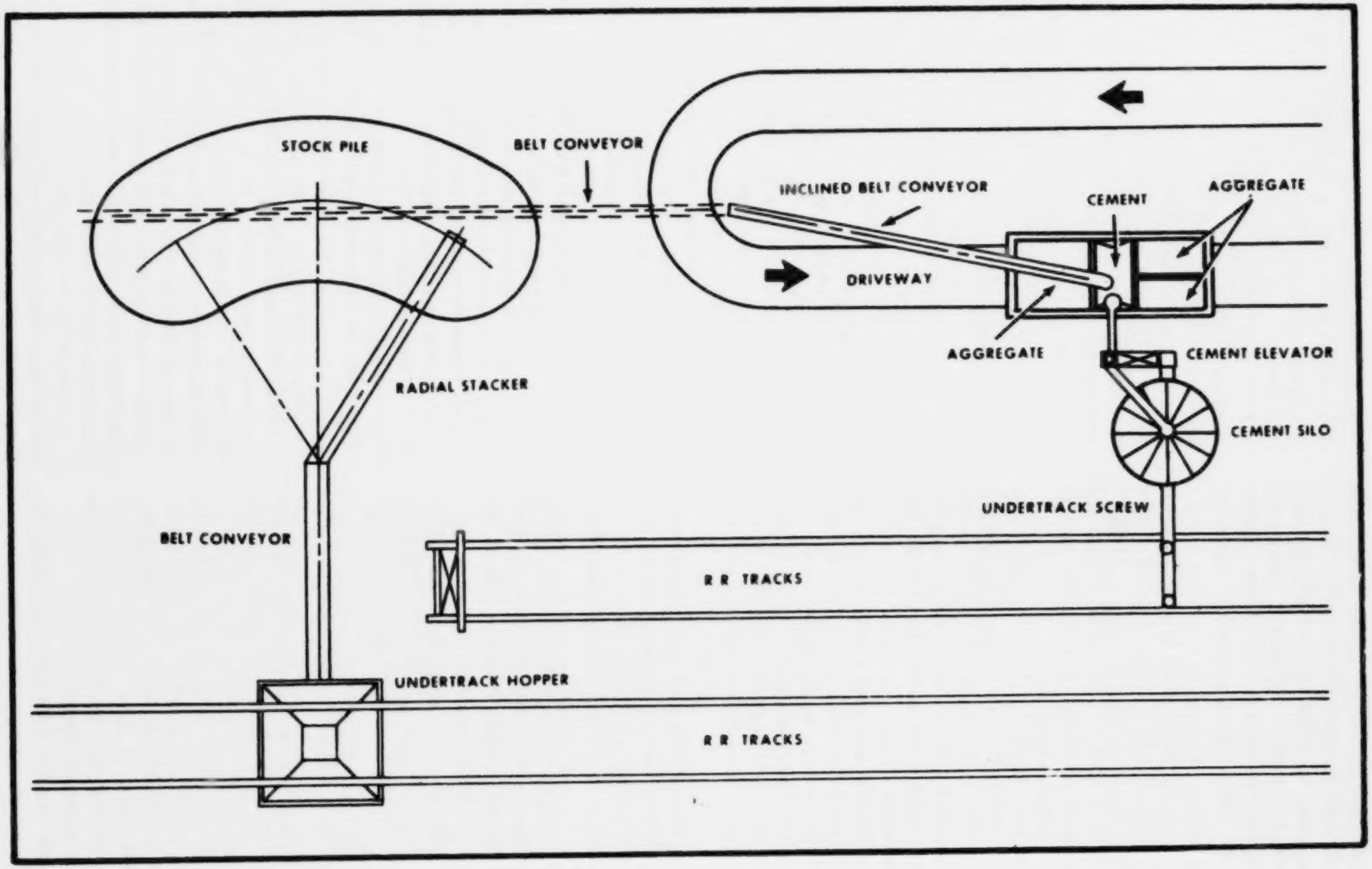

STOCK PILE
BELT CONVEYOR
INCLINED BELT CONVEYOR
CEMENT
AGGREGATE
DRIVEWAY
AGGREGATE
CEMENT ELEVATOR
RADIAL STACKER
CEMENT SILO
UNDERTRACK SCREW
BELT CONVEYOR
R R TRACKS
UNDERTRACK HOPPER
R R TRACKS

Figure 84. Typical layout for a one-stop batch plant.

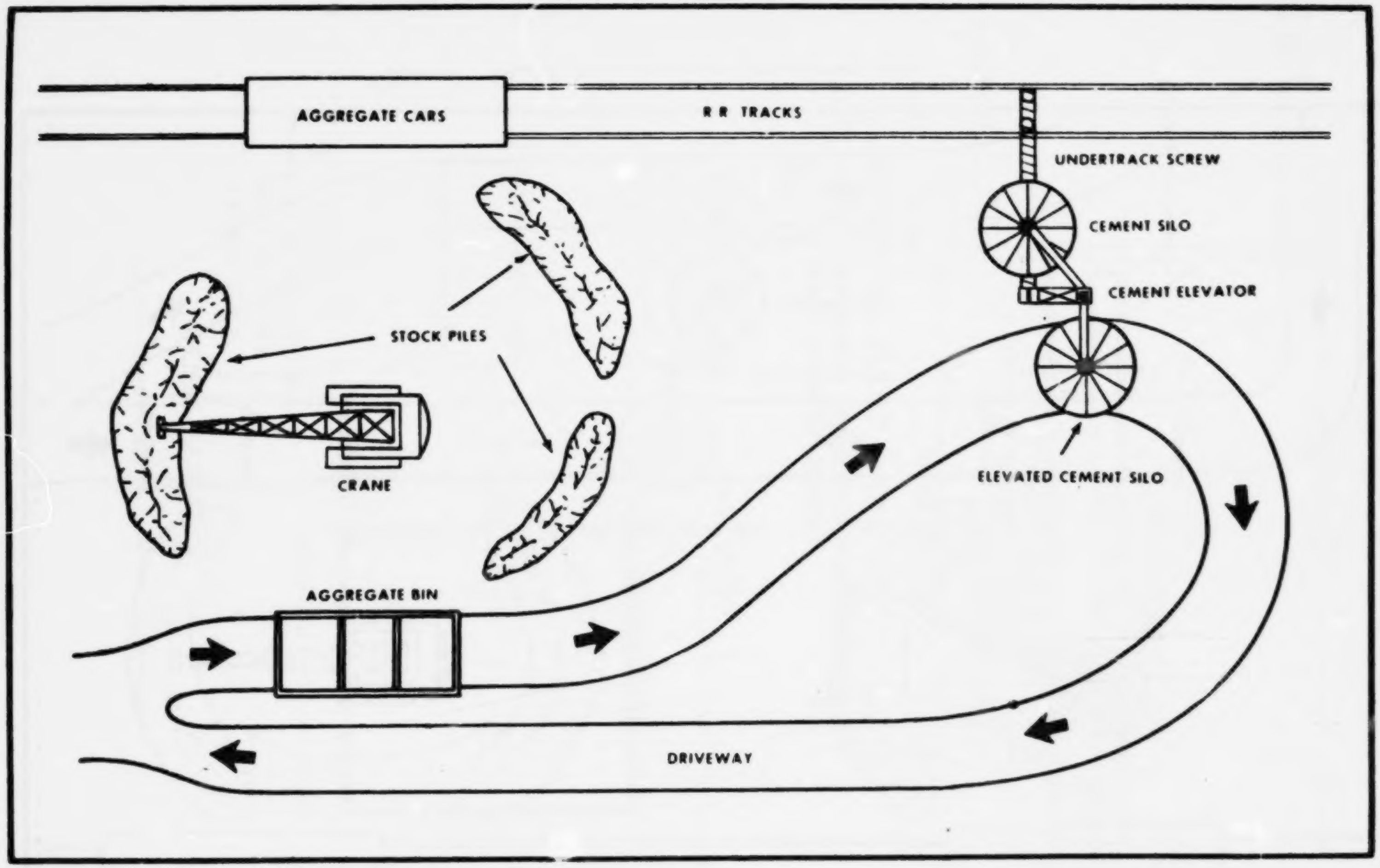

AGGREGATE CARS
R R TRACKS
UNDERTRACK SCREW
CEMENT SILO
CEMENT ELEVATOR
STOCK PILES
CRANE
ELEVATED CEMENT SILO
AGGREGATE BIN
DRIVEWAY

Figure 86. Typical layout for a two-stop batch plant.

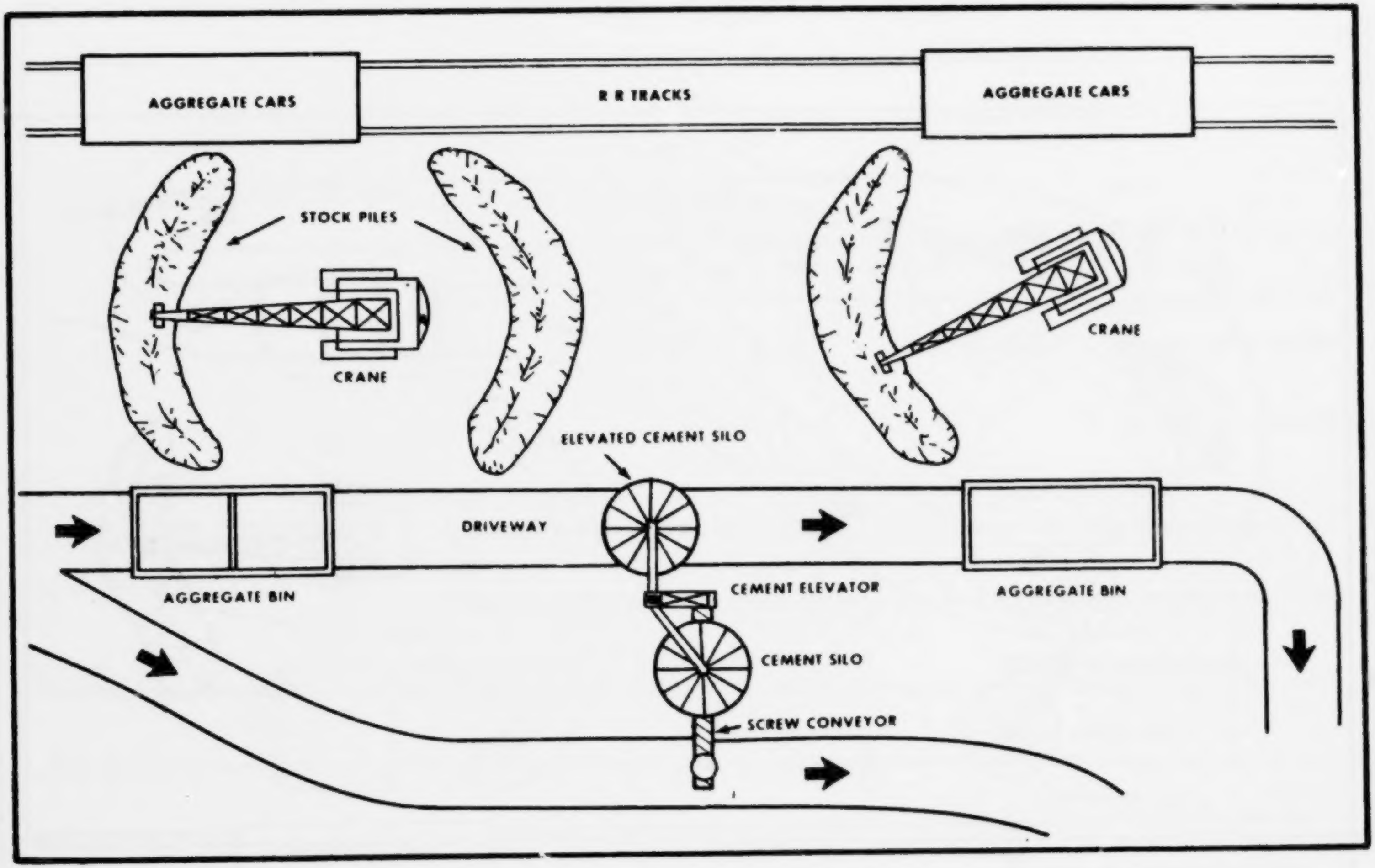
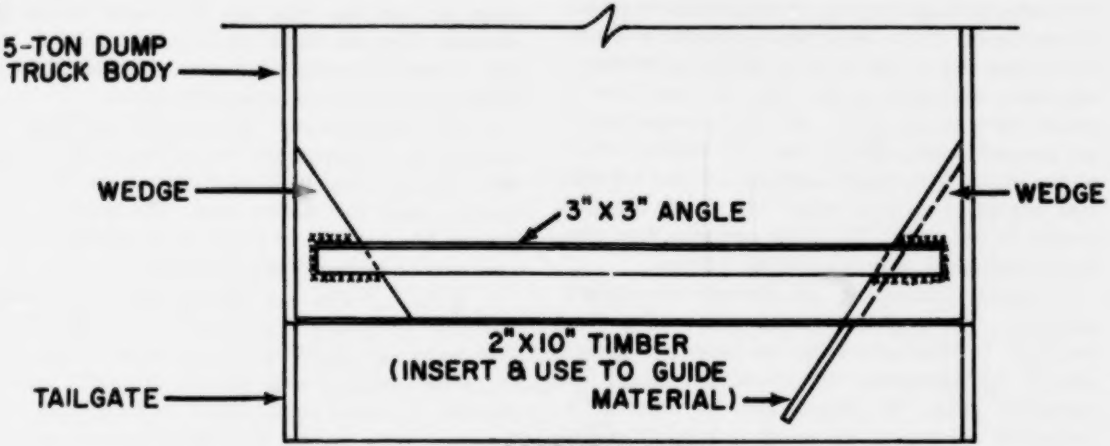
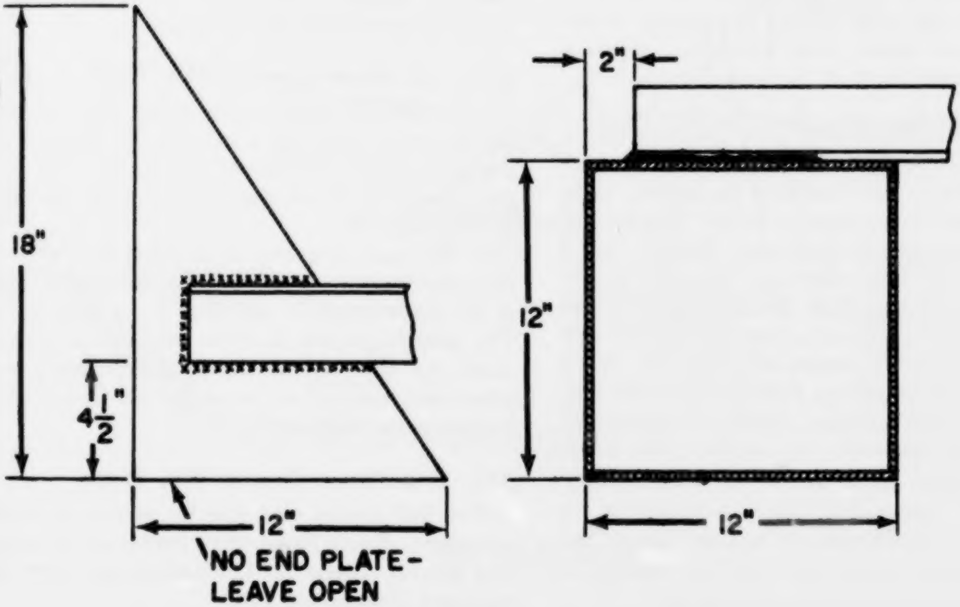

AGGREGATE CARS
R R TRACKS
AGGREGATE CARS
STOCK PILES
CRANE
CRANE
ELEVATED CEMENT SILO
DRIVEWAY
AGGREGATE BIN
CEMENT ELEVATOR
AGGREGATE BIN
CEMENT SILO
SCREW CONVEYOR

Figure 86. Typical layout for a three-stop batch plant.


5-TON DUMP TRUCK BODY
WEDGE
WEDGE
3" X 3" ANGLE
2" X 10" TIMBER (INSERT & USE TO GUIDE MATERIAL)
TAILGATE

ASSEMBLY VIEW

NOTES: 1) ALL PLATES $\frac{3}{16}$" OR $\frac{1}{4}$" STEEL
2) WEDGES SPACED TO INSURE SNUG FIT
3) ALL JOINTS WELDED


18"
$4\frac{1}{2}$"
12"
NO END PLATE- LEAVE OPEN
2"
12"
12"

WEDGE ASSEMBLY

Figure 87. Expedient aggregate guide for 5-ton dump truck.

may be realized by dividing the bed into three compartments. The major disadvantage is the relative difficulty in getting the materials into the proper compartment. If the batch plant is located at a central mixing site, it may be more efficient to construct expedient aggregate guides (fig. 87) and haul a single batch to the mixer. Multiple compartments are generally more efficient when the mixing is done at the paving site; single batching is better for central mixing operations where the batch plant is located at the mixer. The latter operation may also be accomplished with a conveyor system.

i. Closing Operations. At the end of a day's operation, the aggregate batch plant should be emptied. In freezing weather this becomes a necessity or the aggregates will freeze and bridge the clamshell gates. It should also be done in a temperate climate or the moisture content of the first few batches will be higher than the batches that follow. The moisture will tend to consolidate in the bottom third of the bin during the evening and adjustments will become necessary at the paver to insure a constant water-cement ratio. The supervisor of the batch plant should lock up the scale beam box so that only he can change the weight settings on the scales. This will insure constant accurate proportioning of the aggregates.

258. Central Mix Plants

The central mix plant differs from the other type plants in that it has facilities to handle, store, batch, and mix the concrete materials. The batcher is so arranged that it discharges directly into a mixer which, in turn, discharges the mixed concrete into the haulage unit. The haulage unit then hauls the mixed concrete to the construction site. Some advantages of a central mix plant are: better control of concrete through rigid and accurate control of water and moisture content of aggregates; control of the consistency of concrete; and better control through centralization of responsibility. There are no central mix plants currently in the Army system. Paragraphs 260 and 261 discuss two expedient central plants that may be constructed from standard concrete mixing equipment.

259. Central Mix Plant Criteria

a. Location. A central mix plant should be located so that the mix can be placed within 30 minutes. The site should be level with good drainage. A sidehill location is usable, provided there is adequate working area around the mixers.

b. Site Improvement. A retaining wall must be constructed to support the wall of the truck loading well. A sump must be located against the retaining wall to drain the loading well. The working and storage areas should be paved if the plant is to be used over an extended period of time.

c. Water. Water is a critical item at a central mix plant. If water is not available at the site, it may be brought in by truck or pipeline. A pipeline is the best solution as it reduces the traffic around the site. A water point should be located so that the truck beds can be thoroughly cleaned prior to filling with concrete. Locating a source of water is a primary factor in central plant site selection.

d. Road Net. A good net is another primary factor in site selection. In most cases fair weather roads will be acceptable. Concrete paving operations will usually be suspended before bad weather makes unimproved roads impassable.

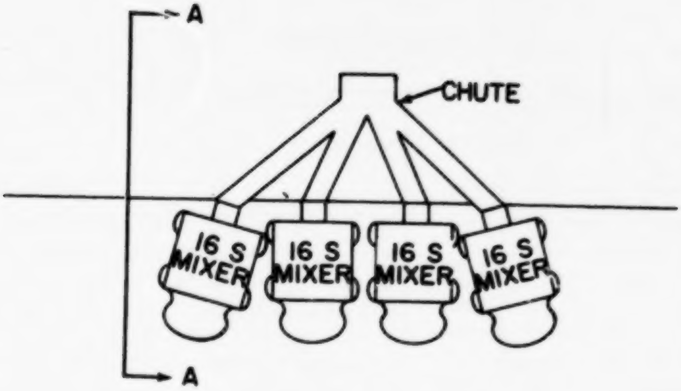
260. 16S Mixer Central Mix Plant

a. An efficient central mix plant may be constructed with four 16S mixers as the basic units. Figure 88 shows a sketch of this layout. The general criteria for this central mix plant are discussed in paragraph 259.

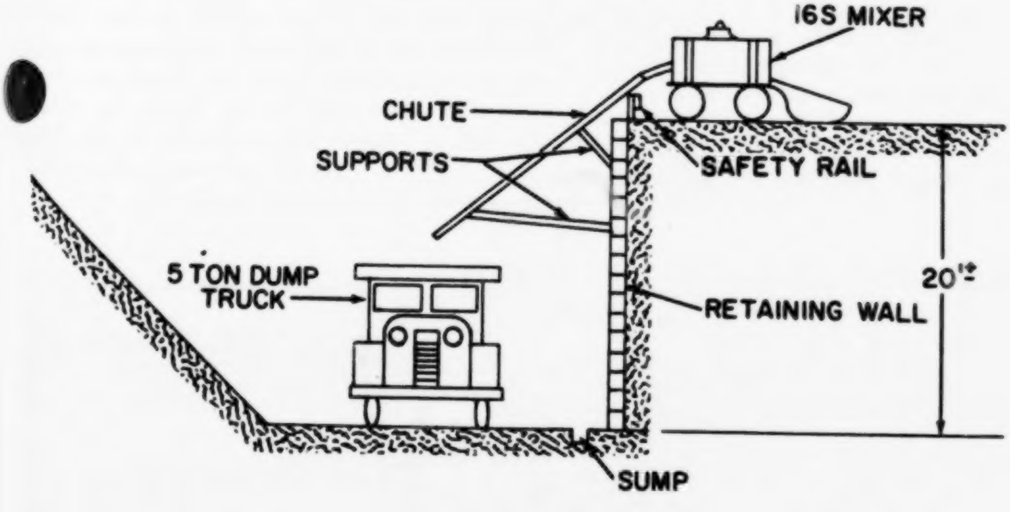
b. The chute (fig. 88) design must be on a trial and error basis. A width of 18 inches and a depth of 12 inches is usually sufficient if the slope is 1:1. The stiffest mix that is to be produced is used to check the slope of the chute. Exceptionally stiff mixes may require the use of shovels or expedient paddles to maintain flow.

261. 34E Paver Central Mix Plant

Two 34E pavers may also be used as a central mix plant. Figure 89 depicts a layout of this plant. The general criteria for this central mix plant are discussed in paragraph 259.


A
CHUTE
16 S MIXER
16 S MIXER
16 S MIXER
16 S MIXER
A

PLAN VIEW


16S MIXER
CHUTE
SUPPORTS
SAFETY RAIL
5 TON DUMP TRUCK
20'±
RETAINING WALL
SUMP

SECTION A–A

Figure 88. 16S mixer central mix plant.

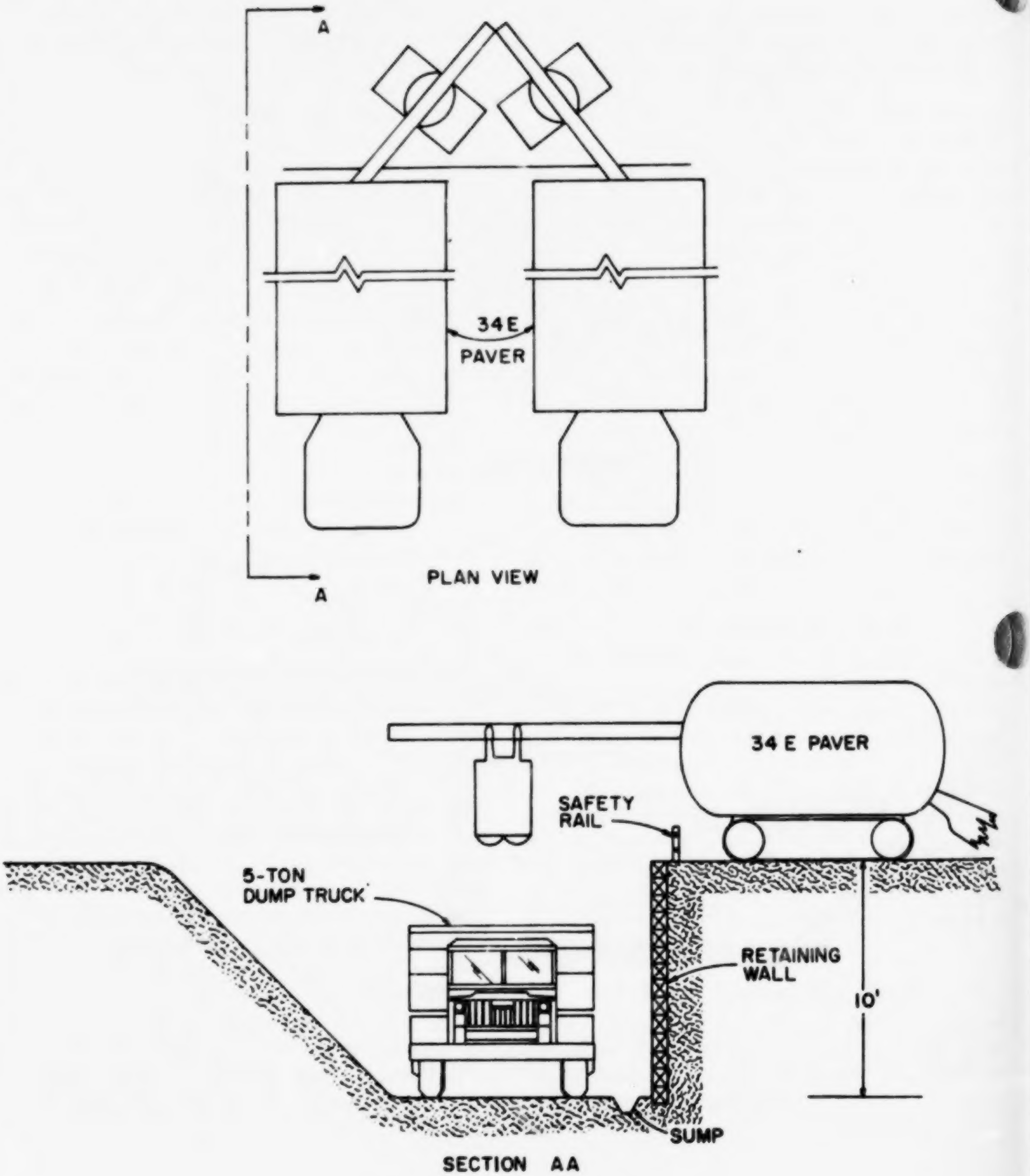

A
34 E
PAVER
A
PLAN VIEW
34 E PAVER
SAFETY
RAIL
5-TON
DUMP TRUCK
RETAINING
WALL
10'
SUMP
SECTION AA

Figure 89. 34 paver central mix plant.

CHAPTER 14

FORMS AND JOINTS

Section I. FORMS

262. Introduction

a. Function of Forms. The riding quality of concrete pavement depends to a large extent upon the quality of support which the forms give to the form riding equipment. Good form alinement does not, by itself, insure a good surface, as bent or inadequately supported forms will contribute to surface irregularities. Steel paving forms have two functions. The first is to contain the concrete in a specific area and the second is to provide a track for the form riding equipment (fig. 90).

b. Description. Steel forms are made in 10-foot lengths and are held in position by three wedged pins and end locks. The weight of the form varies m 204 pounds for 8-inch forms to 292 pounds 12-inch forms. All standard forms have three pin holes in which pins are wedged to hold the forms firmly in position (fig. 91).

c. Pins. Pins of the proper length are inserted in each hole and driven well into the subgrade to hold the form in position. Length of the pins depends upon the height of the forms and the type of subbase or subgrade. They should be at least 18 inches long for 8- or 9-inch forms and should increase to 30 inches for 12-inch forms. They should be longer for the more plastic and lower density subgrades. Well-compacted subbases of high density permit the use of shorter pins by providing good lateral support to the portion of the pin below the forms.

d. Lock Plates. Forms have sliding lock plates at one end to fit under the flanges of adjacent forms and to insure positive alinement at the joints. They should slide easily into locking position. This will help prevent their being battered out of shape during installation and removal. Failure to lock each joint may result in stops during operation of the form riding equipment and irregular surface alinement.

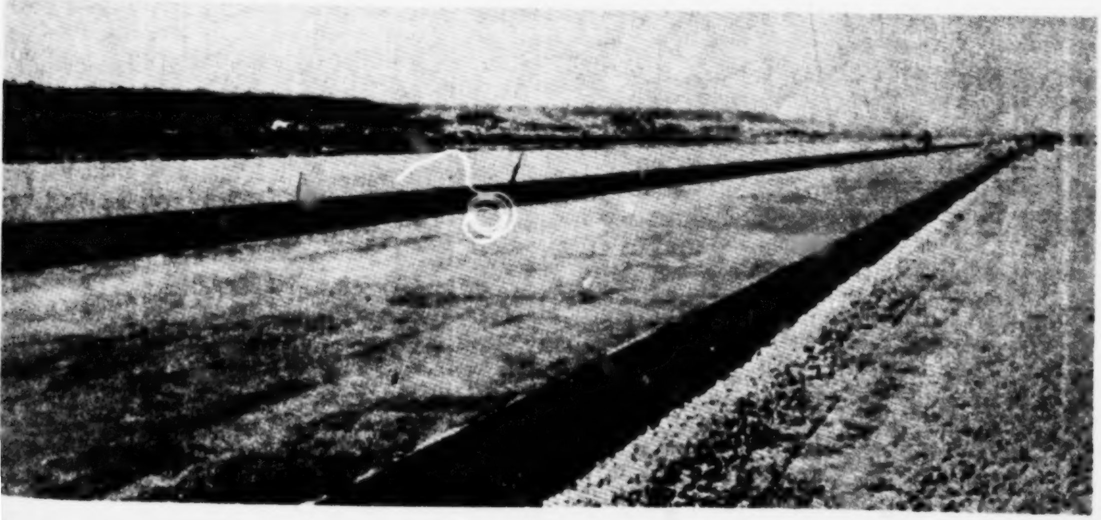


Figure 90. Standard steel forms placed on subgrade.

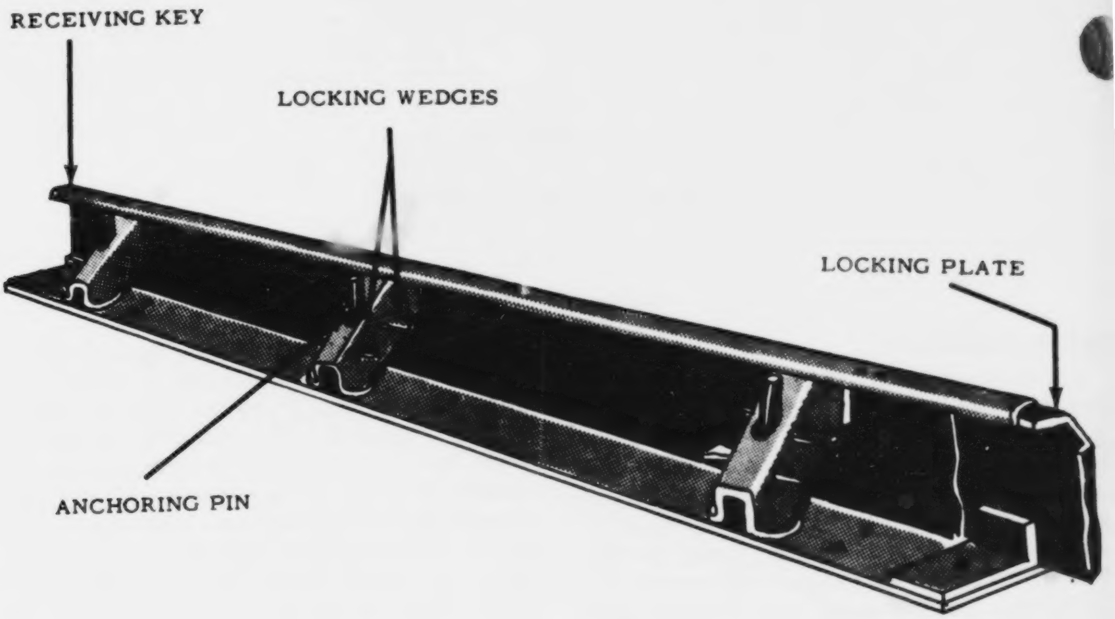


Figure 91. Standard steel concrete form section.

e. Use on Curves. Standard forms are designed so that they can be used on curves with a radius as short as 150 feet. Shorter radii require some type of flexible form, sheet metal or 1-inch wood. Heavy construction of standard forms is not required because form riding equipment cannot turn on sharp curves less than 150 feet in radius. Hand finishing methods will almost always be used under these conditions. Flexible metal or wooden forms are secured into position by stakes driven at frequent intervals to hold them at proper alinement.

263. Use of Forms

a. Height and Width of Forms. The height of the form should be equal to the specified edge thickness of the concrete and the base should be at least 0.8 the thickness of the height. When necessary, the height of the forms can be increased by placing them on wooden risers, provided the thickness of the wooden base does not exceed 25 percent of the original form height. The thickness of the wooden base should be sufficient to bring the dimension of the form up to the required height.

b. Form Base. The base for the forms is trimmed to proper elevation before the forms are placed in position. Before trimming, the surface of the subgrade or subbase should be as high as, or slightly higher than the elevation of the base of the forms so that the forms rest on compacted material.

c. Placement and Alinement. After the for base has been trimmed to the desired elevation, forms are placed, a pin set in each hole, and the forms alined with a stringline. The stringline should be set at the proper height for grading the base for the forms. If grading is done by hand, the stakes are set so that the string is on line with the face of the forms and at the elevation of the top of the forms. It then serves also as a guide for setting forms. If form grading is done by machine, the stringline must be set twice; first on an offset and at a height to meet the requirements of the grader, and the second for form setting as described for hand grading. The stakes should be set at intervals not to exceed 50 feet and as often as 25 feet on vertical horizontal curves. Form pins are then driven, either by hand or by mechanical pin driver (compressed air).

d. Pin Driver. The pin driver (fig. 92) consists of a clay spade (digger or 35-lb pavement breaker) with a modified moil point tool. The sharp end is cut off the moil point and a collar welded on so that the collar rests over the head of the pin. When air is supplied, the clay spade will supply enough force to drive the pin down and the coll

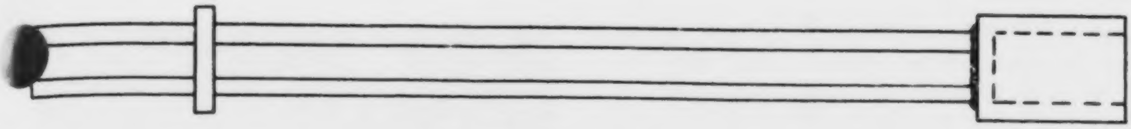


Figure 92. Expedient pin driver.

will keep the tool from vibrating off the head of the pin. Not only does the pneumatic pin driver save manhours (as opposed to the hand sledge method), but it will cut down on the mushrooming effect on the head of the pin that the sledge hammer will produce. With the forms at the proper elevation, wedges and end plates are driven in to hold them firmly in position.

e. Rigidity of Forms. The rigidity of forms and firmness of support should be such that the forms do not deflect more than 1/4 inch when tested as a simple beam carrying a load equal to that of the heaviest equipment that will ride on them. The forms should rest on a firm base their entire length and not on pillars or columns of material. To insure this materials should be tamped under the forms either by the form tamper rolling on the form or by hand with tamping bars. However carefully the forms are placed and alined, there will be minor variations from the proper elevations, particularly at joints. These can be recognized by sighting along the top of the forms.

f. Correction of High and Low Spots. To correct a low spot, the form is raised by loosening the locking wedges and end plates and placing a bar under the base (fig. 93). While the forms are thus

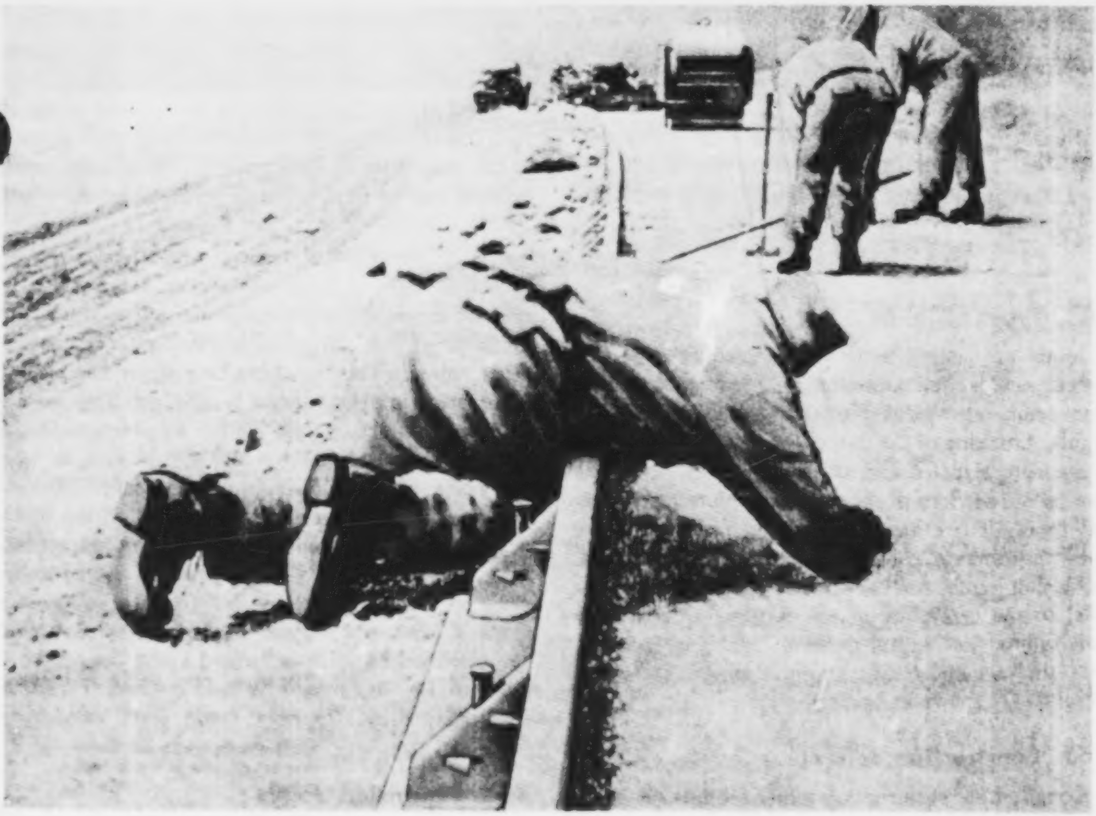


Figure 93. Adjusting low spots in forms.

supported, additional material is tamped beneath them to secure proper elevation. High spots can be corrected by removing one or more lengths of forms and trimming off the high spot or excess material.

264. Storage and Handling of Forms

a. Oiling of Forms. Forms should be oiled immediately before each use by brushing or spraying with used crankcase or form oil. This prevents concrete from stricking to the forms (when using keyways, oil must be used or the removal of the keyway will cause damage to the concrete) and facilitates removal, cleaning, and reuse (fig. 94).

b. Form Removal. Forms can be removed as soon as the concrete slab has hardened sufficiently so that the slab is not damaged by their removal. Pin pullers with adequate bearing on the forms are essential if chipping damage to the new concrete is to be avoided during this operation. The forms should be thoroughly loosened from any spilled concrete, soil, or other material before lifting in order to prevent bending. No form should be used if the top is out of line by an amount greater than the allowance tolerance of the finished concrete surface. This is usually 1/8 inch in 10 feet. With proper handling, forms will retain the straightness that is essential to an even surface finish.

c. Storage. When storing forms before and after use, they should be cleaned and stacked about five forms high to permit ease of handling when they are to be used again.

Figure 94. Application of oil to form before use.

d. Transportation. Unless special bridge trucks are available (with the 22-foot extendable boom), 25-ton low bed trailers are best to transport forms from one area to another. It is permissible to drop forms off the low bed as long as one form is not so rocky as to damage the form when it hits the groun If the area is level, fork lifts or roust-abouts (small cranes) can be used to move forms short distances.

Section II. JOINTS

265. Types of Joints

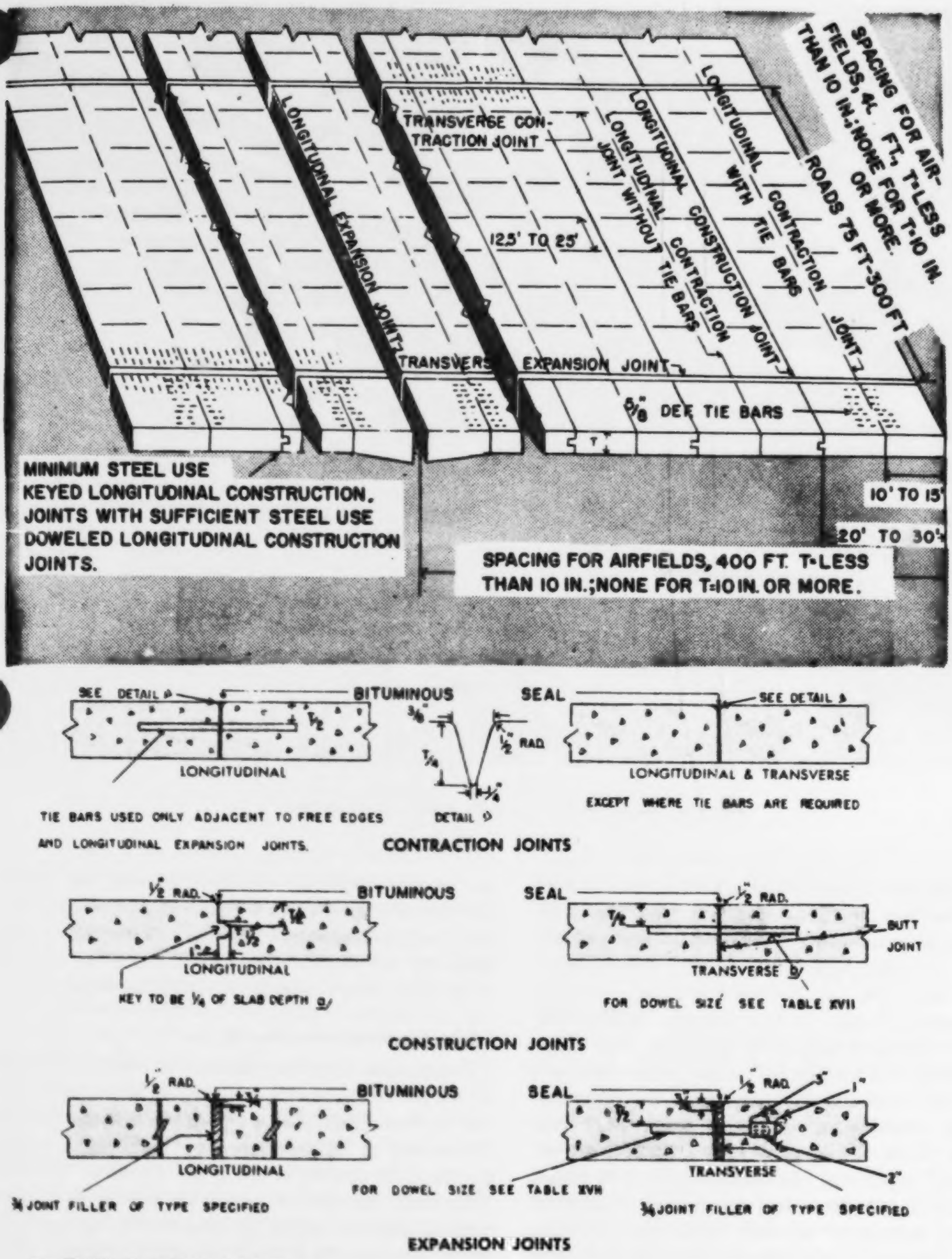
Joints are constructed in concrete pavements to permit contraction and expansion of the concrete from temperature and moisture changes without irregular breaking of the pavement, to relieve warping and curling stresses, and as a construction expedient to separate sections of the pavement placed at different times. There are three general types of joints used in concrete pavements: construction joints, expansion joints, and contraction joints. Joints parallel to the centerline of the pavement are called longitudinal joints, and those at right angles to the centerline are known as transverse joints. The types of joints are shown in figure 95.

266. Construction Joints

Longitudinal construction joints are formed along the interior edges of each paving lane in accordance with design criteria. These joints are either doweled or keyed. Transverse construction joints are installed at the end of each day's placing, and at other points within a paving lane where the placing of concrete is discontinued a sufficient time for the concrete to start setting. So far as practicable, the transverse construction joint is installed to take the place of a planned transverse contraction or expansion joint. When this is not feasible, the transverse construction joint should be installed not less than 10 feet from the closest regularly spaced transverse joint. All transverse construction joints at a planned joint location should be doweled, but when the construction joint is formed along the center of the slab, tie bars should be used instead. Figure 96 shows expedient tie bars made from reinforcing bars.

267. Expansion Joints

Expansion joints (fig. 97) are used in pavements less than 10 inches thick, at intersections of a


SPACING FOR AIRFIELDS, 4C FT. T-LESS THAN 10 IN.; NONE FOR T-10 IN. OR MORE.
ROADS 75 FT-300 FT
LONGITUDINAL CONTRACTION JOINT WITH TIE BARS
LONGITUDINAL CONSTRUCTION JOINT
LONGITUDINAL CONTRACTION JOINT WITHOUT TIE BARS
TRANSVERSE CONTRACTION JOINT
LONGITUDINAL EXPANSION JOINT
12.5' TO 25'
TRANSVERSE EXPANSION JOINT
5/8" DEF TIE BARS
T
MINIMUM STEEL USE KEYED LONGITUDINAL CONSTRUCTION. JOINTS WITH SUFFICIENT STEEL USE DOWELED LONGITUDINAL CONSTRUCTION JOINTS.
10' TO 15'
20' TO 30'
SPACING FOR AIRFIELDS, 400 FT. T-LESS THAN 10 IN.; NONE FOR T=10 IN. OR MORE.
SEE DETAIL b
BITUMINOUS SEAL
T/2
LONGITUDINAL
TIE BARS USED ONLY ADJACENT TO FREE EDGES AND LONGITUDINAL EXPANSION JOINTS.
3/8"
1/2" RAD.
T/4
1/4"
DETAIL b
SEE DETAIL b
LONGITUDINAL & TRANSVERSE
EXCEPT WHERE TIE BARS ARE REQUIRED
CONTRACTION JOINTS
1/2" RAD.
BITUMINOUS SEAL
T/2
T/2
1"
LONGITUDINAL
KEY TO BE 1/4 OF SLAB DEPTH a/
1/2" RAD.
T/2
BUTT JOINT
TRANSVERSE b/
FOR DOWEL SIZE SEE TABLE XVII
CONSTRUCTION JOINTS
1/2" RAD.
BITUMINOUS SEAL
LONGITUDINAL
3/4 JOINT FILLER OF TYPE SPECIFIED
FOR DOWEL SIZE SEE TABLE XVII
1/2" RAD.
3"
1"
T/2
TRANSVERSE
2"
3/4 JOINT FILLER OF TYPE SPECIFIED
EXPANSION JOINTS

a/ DO NOT USE KEYED CONSTRUCTION JOINT FOR SLAB WITH T LESS THAN 8 INCHES.

b/ ALSO LONGITUDINAL JOINTS WHEN SUFFICIENT DOWELS AVAILABLE.

Figure 95. Types of concrete joints.

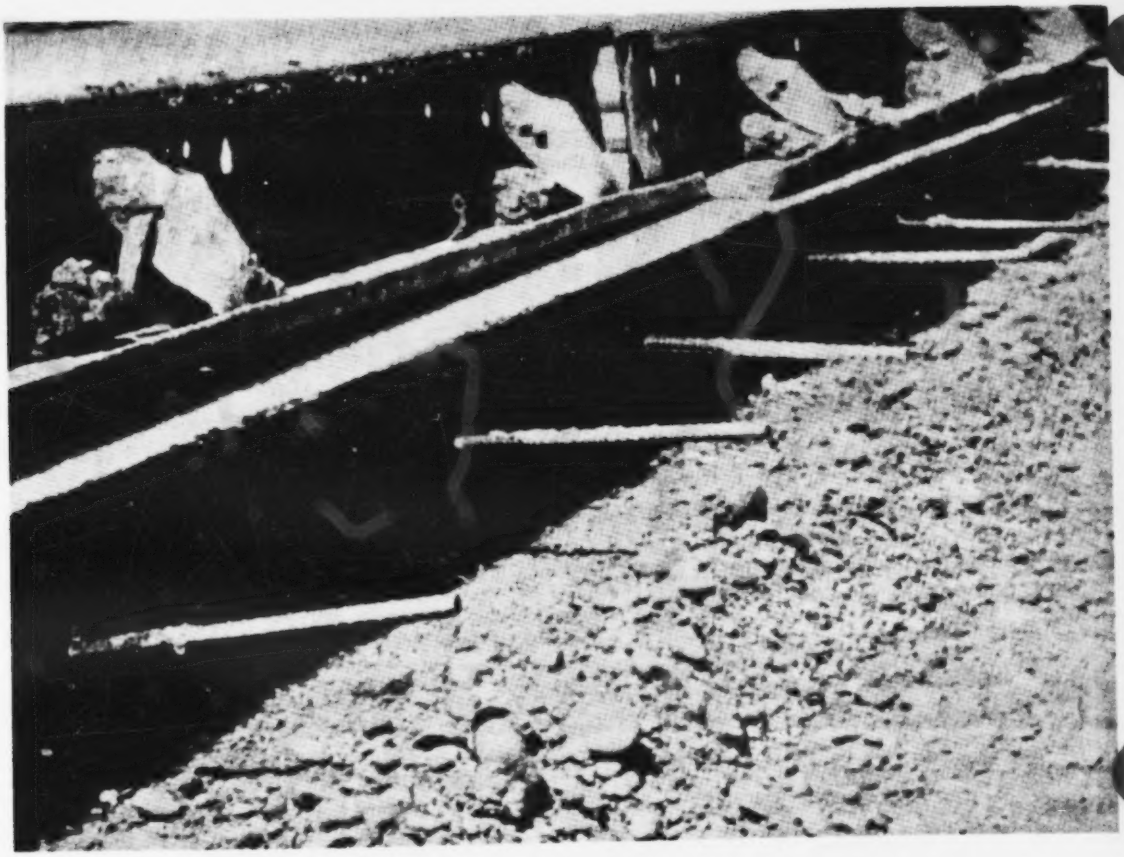


Figure 96. Expedient tie bars made from reinforcing bars.

pavements, and around all structures in contact with the pavements. The purpose of the expansion joint is to permit expansion movement of the concrete without disturbing the adjacent structure or intersecting pavement, and to avoid creating excessive compressive stresses in the concrete which may result in blowup of sections of the pavement. There is less danger of blowup of thicker pavements, and expansion joints are not used when the pavement has a thickness of 10 inches or more, unless the concrete contains aggregate with a high coefficient of thermal expansion. In slabs less than 10 inches thick, expansion joints may be omitted if concrete is placed during hot summer conditions. The expansion joint filler may be wood board or preformed bituminous treated fiber conforming to specification requirements and having specified dimensions. Dowels are required for all transverse expansion joints to maintain alinement of the adjoining slabs and to provide load transfer between the slabs. Thickened edge slabs are required at free, undoweled, longitudinal expansion joints. These free joints generally are installed in large paved areas, and at ridge lines where change of grade is required.

268. Contraction Joints

Contraction joints are installed to control cracking of the pavement during contraction of the concrete, and to limit curling or warping stresses created by differences of temperature and moisture between the top and bottom of the slabs. Longitudinal and transverse contraction joints are planes of weakness formed by cutting grooves in the top portion of the pavement to a depth necessary to assure contraction cracking at the joint. These joints may be formed in the plastic concrete during construction of the pavement, or sawed in the pavement after it has hardened. The weakened plane joints

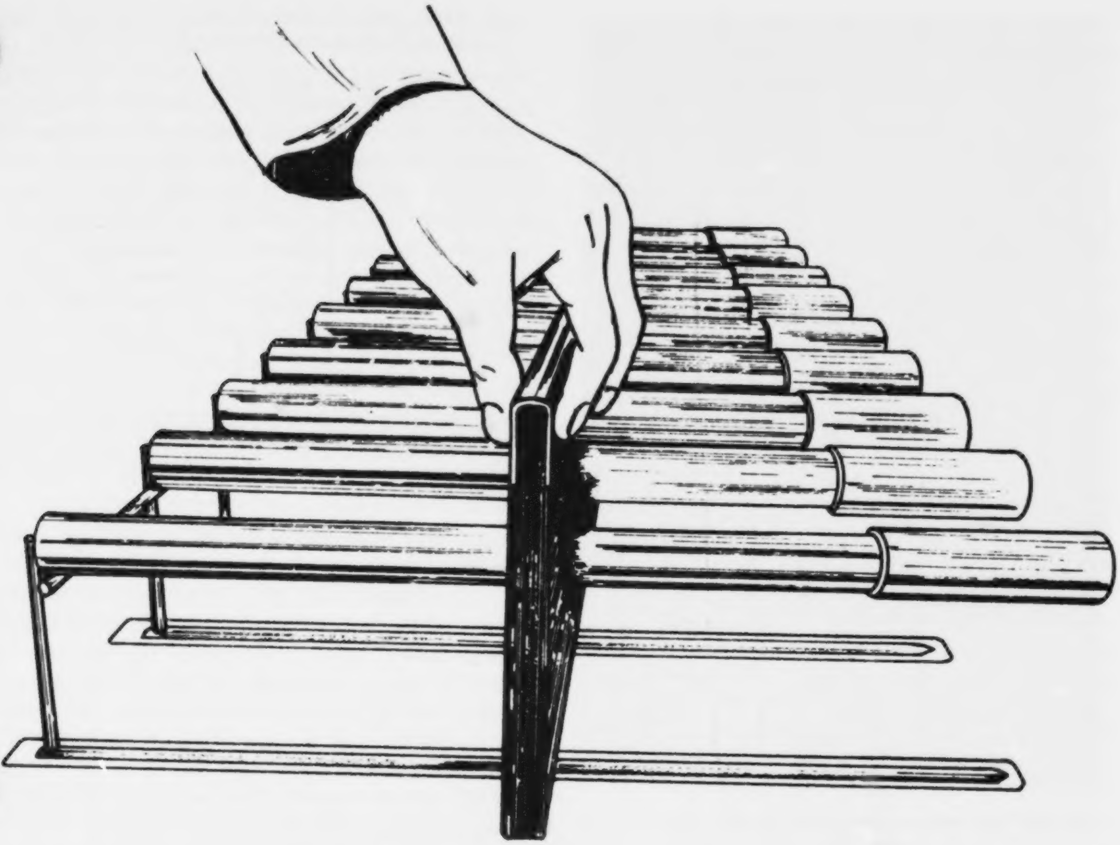


Figure 97. Expansion joint assembly.

(also known as dummy joints) should be constructed with the spacing and details specified in the design criteria. For pavements having a thickness of 10 inches or more, the spacing of the transverse contraction joints should be equal to the width of the paving lanes, usually 20 to 25 feet. However, concrete made with certain types of aggregate, such as slag, may have higher than normal shrinkage characteristics and require closer joint spacing. For contraction joints, the depth usually should be equal to one-fourth of the pavement thickness. The cost of sawing joints is directly related to the depth of cut, and the least depth possible should be determined by trial in the field. When no concrete saw is available, contraction or dummy joints can be constructed, through the use of a steel form ¼"×4"×19¾". Hooks are welded to the top edge of the form to enable pulling out after the concrete has set. The form is coated with heavy grease and bond paper is applied. The steel form is then inserted in the concrete by tapping with a hammer or by use of a vibrator. The form can be readily pulled after set occurs, leaving a clean vertical joint. Figure 98 shows a contraction joint that has cracked correctly after initial contraction.

269. Dowels

Dowels are mechanical load-transfer devices built as an integral part of certain transverse joints. When used, they are installed across a joint in such a way as to permit the joint to open and close but to hold the slab ends on each side of the joint as nearly as possible at the same elevation. The deflection of one slab under load is resisted (through the dowel) by the other slab which, in turn, is caused to deflect and thus to carry a portion of the load imposed upon the first slab. Dowels are used for all transverse expansion joints and all transverse construction joints installed at a planned joint. They also may be used in longitudinal construction

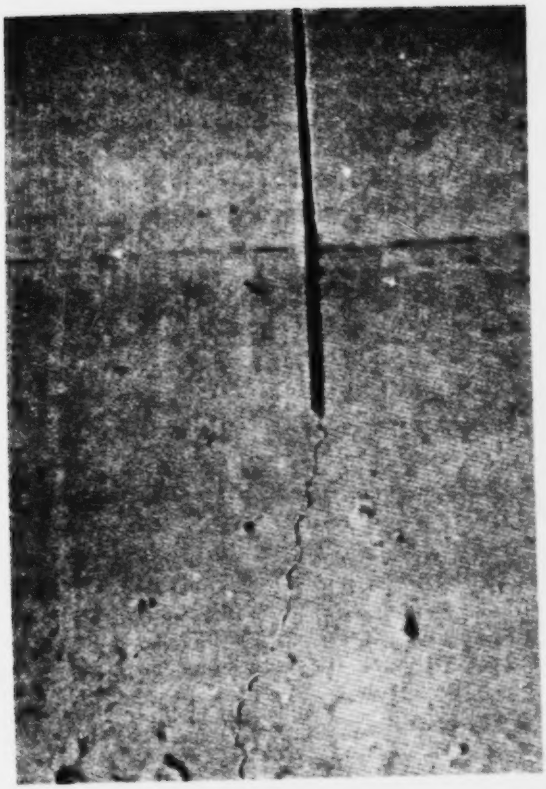


Figure 98. Contraction joint that has cracked correctly after initial contraction.

Table XVII. Guide of Approved Sizes of Dowels for Construction, Dummy, and Transverse Expansion Joints

Pavement thickness	Minimum dowel length	Maximum dowel spacing	Diameter of dowel	Type of dowel *
Less than 8"	16"	12"	¾"	Steel bar
8" to 11"	16"	12"	1"	Steel bar
12" to 15"	20"	15"	1¼" 1"	Steel bar or Extra-strength pipe
16" to 20"	20"	18"	1½"	Steel bar or Extra steel pope
21" to 25"	24"	18"	2"	Extra-strength pipe or steel bar
Over 25"	30"	18"	3" 3"	Steel bar or Extra-strength pipe

* When extra-strength pipe is used, the pipe will be filled with either a stiff mixture of sand-asphalt or cement mortar or the ends of the pipe will be plugged. If the ends of the pipe are plugged, the plug must fit inside the pipe and be cut off flush with the end of the pipe so that there will be no protruding material to bond with the concrete and prevent free movement of the dowel.

joints and in special locations at the outside lanes or slabs of the pavement. The diameter, length, and spacing of the dowels vary with the pavement thickness. All dowels should be straight, smooth, and free from bur at the ends. Half of the length of the dowel is painted and greased to prevent bonding with the concrete. Dowels used in expansion joints are capped at the end, which is painted and greased to provide a space for movement of the dowel when the concrete expands and closes the joint. Dowels used in construction joints or in other locations where a filler is not installed, should be of the same size, type, and spacing as for transverse expansion joints, but should not be capped. A guide of approved sizes of dowels is shown in table XVII.

270. Installation of Joints

a. Basic Considerations. Although joints are necessary in concrete pavement, even the best joints are points of weakness, both with regard to load stresses and to deterioration by weathering. Most failures of concrete pavements start at the joints and every effort should be made to provide the best possible joint. Continuous inspection is required before, during, and after the concrete is placed to assure that only the best joints are obtained. All joints should be constructed perpendicular to the finished grade of the pavement. Transverse joints should be at right angles to the centerline of the pavement, and should be continuous along a straight line through all lanes in a paved area. Longitudinal joints should be parallel to the centerline of the pavement at the required spacing. All expansion and construction joints are installed prior to placement of the concrete. Contraction joints are formed after the concrete is placed, and require earlier inspection only when tie bars or dowels are used in these joints. Reinforcement or steel other than the required dowels or tie bars should not extend through any joint.

b. Longitudinal Construction Joints. Longitudinal construction joints are defined by the forms. When dowels are used, they should be checked to see that they are of the required size, and that they are accurately installed in the forms at the required spacing and location. The dowels should be held securely and accurately in position so that they will not be displaced during placement of concrete. The forms usually have an outside channel or other holding device for maintaining the dowels in position. The depth of embedment should be checked during placement of the concrete. The practice is to embed the fixed portion of the dowel during the first placing operation. The exposed portion of the dowel is then painted and greased prior to placing the adjoining lane. When keyed longitudinal joints are required, the key form should preferably be made of steel and should be fastened securely to the pavement form in the required location. However, there are no steel keys in the current supply system and wood is used in lieu of steel.

c. Transverse Construction Joints. Transverse construction joints are installed at the completion of the paving operation and are generally formed by means of a temporary bulkhead installed between, or at the end of, the forms. Care should be taken to see that the bulkhead is securely fastened in place. Dowels are installed when the transverse construction joint is at the location of a scheduled joint. When concrete placement is stopped at the interior of a slab, tie bars are placed in the joint to form a continuous slab unit when additional concrete is placed in the slab. The next regular joint should then be constructed in the planned location.

d. Expansion Joints. Expansion joints are the most difficult to set and maintain in their correct position, and these joints should be carefully checked throughout the paving operation. The expansion joint filler and dowels, or other load-transfer devices, should be held securely in place by means of suitable installing devices (fig. 97). The joint filler is held in a vertical position and should be well supported so that it will not be disturbed or damaged during the concreting operations. The subgrade should be carefully prepared and the joint material cut accurately so that it will extend continuously from the required position at the top of the slab and from edge to edge of the pavement.

(1) *Placement of concrete.* While the concrete is being placed, the top edge of the filler should be protected with a metal channel cap, which will form a space for the poured sealer when it is removed. Dowel bars should be held accurately in place, parallel to the surface and the centerline of the slab, with metal baskets or other installing devices. The method used in holding the bars in position should develop such accuracy that the error in alinement of any bar in the entire installation is reduced to a minimum. Bars should be checked with a template. The free end of each dowel should be painted with one coat of red lead or other approved paint. After the paint has dried, the free end of the dowel is thoroughly coated with heavy oil or grease and provided with close fitting expansion caps. Any displacement of dowels in excess of the allowable tolerance should be immediately corrected.

(2) *Final position checks.* The horizontal position of the dowels may be checked with a steel tape with the bar spacings marked thereon. The vertical position is then checked with a dowel bar checker, which is essentially a rectangular U-frame, having two legs of equal length with an adjustable level mounted on the cross bar. The legs should have a length of about 10 inches and should be spaced 12 inches apart for checking 16-inch dowels and 16 inches apart for checking 20-inch dowels. The level is adjusted to compensate for the grade of the pavement, by placing the checker on top of forms at each expansion joint and centering the bubble. The legs of the checker are then set on the dowel bar, straddling the joint which should be equidistant between the legs. The position of the level bubble should be within a limiting mark for the specified tolerance, which is determined by trial prior to the use of the checker. When a dowel bar checker is not available, the vertical position of the dowels may be checked with a level and rod, with proper allowance being made for grade of the pavement.

(3) *Joint surface.* The surface of the concrete at the joint should be carefully finished and checked with a straightedge to see that it will provide a smooth riding surface. The top edges of the joint are rounded with a suitable edging tool, and any concrete which has entered the space above the joint filler is removed during the finishing of the joint. When the side forms are removed, any wedges of concrete across the ends of the joints should be removed. If any concrete is left spanning the joint, it will prevent free expansion, and spalling will result.

e. Contraction Joints. Contraction joints of the weakened plane (dummy) type are formed by grooving the top portion of the freshly placed concrete with a suitable tool, or by sawing the grooves in the pavement after the concrete has hardened. In general, the weakened plane joints are constructed without any steel in the joint, and load transfer is dependent on interlock of aggregate and mortar in the fractured plane below the joint opening. When dowels or tie bars are required in the contraction joints, they should be installed before the concrete is placed, using baskets or other suitable supports for holding the steel accurately in place during the paving operations. In the case of dowels, the alinement should be checked with an adjustable level as discussed in *d* above.

(1) *Hand formed joints.* The weakened plane joints are formed in the plastic concrete by means of a metal bar or other tool which will produce a groove of the required dimensions in the top of the slab. The joints must be formed when the concrete has hardened to the proper point. If the joints are formed too soon, the concrete will tend to sag under the pressure of the forming tool and leave a depressed area in the region of the joint. Also, the concrete will tend to flow together again when the bar is removed and the surface is finished. If the concrete is too hard, the forming tool will disturb the concrete when the pressure required to insert the forming tool is applied, and when the tool is withdrawn. Forming the joint too late tends to produce a high joint. Even slight irregularities in the region of the joint tend to produce a rough riding surface and the joint forming should be carefully inspected to avoid faulty joints.

(2) *Sawed joints.* There are many advantages in sawing joints (fig. 99). No hand finishing is necessary at the joints, which reduces the number of finishers required. The continuous machine finishing of the pavement provides a smoother, better riding surface. Manipulation of the concrete after it is placed and has partially set is avoided. This should reduce the deterioration which is common at joints. Curing compounds can be applied earlier and because the joints are sawed afterwards, there is no necessity for removing the compound from the joint prior to joint sealing.

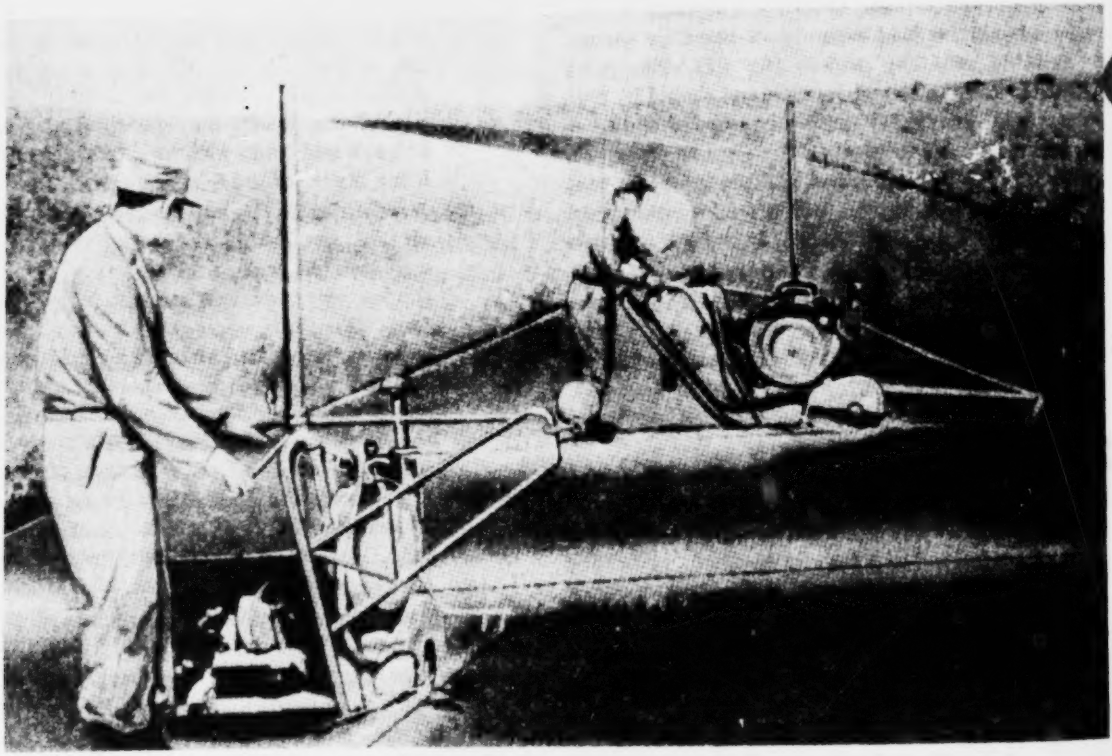


Figure 99. Sawing contraction joints.

(a) *Time of sawing.* Joints must be sawed after the concrete has hardened so that it will not be torn or disturbed by the sawing and before cracking occurs. No definite time of sawing can be set, as this will vary with the many conditions that influence the hardening of the concrete, such as consistency of the concrete, air temperature, humidity, or wind. The time of sawing can be readily determined in the field by examining the concrete or by making a trial cut. It is important to be prepared to saw when the concrete is ready for sawing, regardless of when this occurs. On some projects, sawing may be done within about 6 hours after the concrete is placed during hot, dry weather. During cold weather, the sawing may be delayed as long as 24 hours. For efficient operation, the sawing machine must have ample power to maintain the required speed of rotation of the sawing blade under all operating conditions. Diamond blades generally are used for sawing the concrete, and the blade life will be prolonged by the use of plenty of water during sawing.

(b) *Procedures.* Two general procedures may be used in sawing joints. In one, control joints are hand formed or sawed in the concrete at intervals of about 80 to 100 feet and the intermediate joints are sawed later. With the other procedure, no control joints are used and the joints are sawed consecutively since the concrete is placed as soon as the concrete is ready for sawing. It is believed that the consecutive sawing of joints is the better procedure and that the control joints serve no useful purpose. The use of control joints does not eliminate the danger of cracking between these joints when the intermediate sawing is delayed.

(c) *Guidelines.* A suitable guide should be provided to assure that the joint will be sawed in a straight line. Mechanical guides may be used, but these can cause considerable delay in sawing because of the time consumed for their installation and movement between joints. A chalk line marked on the pavement has been found satisfactory as a guide, if the sawing is done carefully. The groove should be thoroughly flushed out with water as soon as the sawing is completed. The sawed joints are about 1/8-inch wide. The top should be enlarged to a width of between 3/8 and 5/8 inches for a depth of between 5/8 and 7/8 inches to provide suitable space for sealing the joint.

271. Sealing of Joints

Openings in joints are sealed with poured joint sealers to prevent movement of moisture between the pavement surface and the subgrade, and to prevent the entrance of any solid materials that may cause spalling of the concrete at the joint under the action of traffic (fig. 100). The joints are sealed as soon as possible following the curing period. However, sealing should not be done when the air temperature is below 50° F., nor during wet weather when the joints cannot be kept dry. Before sealing,

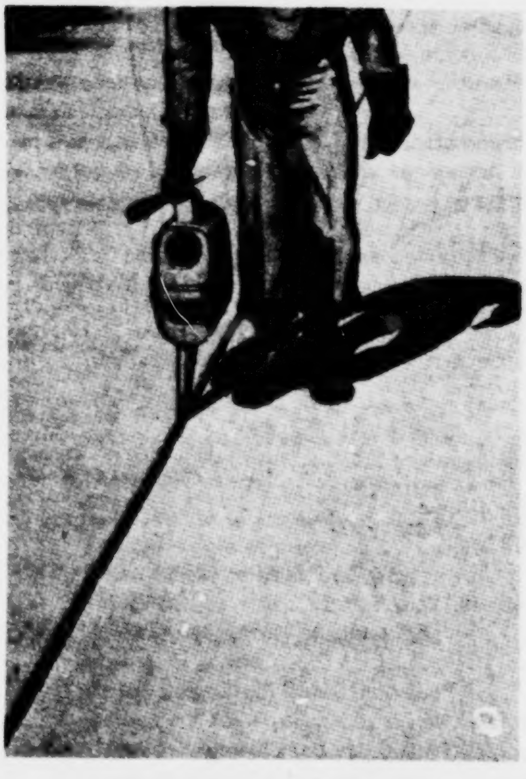


Figure 100. Sealing a joint.

the joints are thoroughly cleaned by a power driven saw blade, sand blasting, and compressed air or with a suitable joint cleaning machine. Sawed joints tend to retain some of the cuttings from the sawing operation and special care should be taken in cleaning these joints. Material in the sawed joints can readily be loosened by operating a wornout saw blade in the joint without the use of water. Hot-poured or cold applied sealers are used for airfield pavements. Material is heated in suitable containers that will maintain a constant temperature throughout the material by keeping it thoroughly agitated. The temperature of the material should be carefully controlled within the temperature range recommended by the manufacturer, which produces a satisfactory pouring consistency. The sealer should not be overheated, as this will generally affect its quality. Sealers should not be reheated, and any material left in the heating pot when the sealing is completed should be wasted. Also, holding the sealing material at the pouring temperature for a long period may affect its quality, and the sealer should be melted and used as required without delay. The joints should be filled flush with the pavement surface, and excess material spilling over the pavement should be removed. Equipment for installing cold-applied sealers should be in accordance with recommendations of the manufacturer. A jet-fuel-resistant material should be used on airfields for jet aircraft.

CHAPTER 15

CONCRETE PAVING OPERATIONS

Section I. MEASURING MATERIALS AND TRUCK REQUIREMENTS

272. Measuring Cement

a. Sacked Cement. Sacked cement is generally used in such a way that the size of the batch will require an even number of sacks. It is unnecessary to weigh the cement since each sack contains 94 pounds of cement.

b. Bulk Cement. If bulk cement is used, the cement must be weighed for each batch. This is usually done by using a bulk cement plant in which the cement is stored in a bin equipped with a weighing hopper. The weighing hopper should discharge through a canvas tremie directly into the charging hopper on the mixer if a central mix plant is used. If a central mix plant is not used, the batcher is equipped with a flexible hose through which the cement is dropped into the batch trucks. A cement batching plant is shown in figure 72.

273. Measuring Water

a. Automatic Water-Measuring Devices. Water for mixing must be accurately measured for every batch. The water tanks of machine mixers are equipped with measuring devices for this purpose. After the tank is filled, the water is siphoned off. The amount of water going to the mixer is controlled by a predetermined setting of the measuring device. Continual maintenance and periodic checks on the quantity of water delivered assure proper operation of the measuring device.

b. Adjustment of Amount of Water Added at Mixer. Water should never be added without measurement. The amount of water required for mixing includes the surface water in the aggregates which is determined as described in TM 5–530. Adjustment for moisture content is described in paragraph 225.

c. Measuring Water by Pail. If the automatic water measuring device on the mixer is not functioning correctly, a galvanized pail may be used to measure the water. Whole, half, and quarter gallon marks may be painted on the inside. This pail should be kept at the mixer and used for this purpose only.

274. Measuring Aggregate

The aggregate to be used for each batch should be accurately measured. Aggregate should be measured by weight. Volume measurement should be used only if weighing equipment is not available. Measurement by weight is more reliable since the accuracy of volume measurement depends entirely upon the accuracy of an estimate of the amount of bulking. The amount of bulking varies according to the moisture in the sand.

a. Measurement by Weight. The measurement of aggregates for paving operations by weight is the most accurate and efficient. The aggregate batching plant (para 236) should be used if possible. Truck scales may be used as an expedient measuring device. Cement may be added in this manner also, although the accuracy may vary about one-half bag. This method will be accurate within 20 pounds if the scalers are in good condition.

Example and Solution: The following is an example and the solution of a typical batch measurement by weight situation—

(1)	Total weight of truck	20,810 lbs
(2)	Desired weight of gravel	3,000 lbs
(3)	Gross weight of truck and gravel (1) + (2)	23,810 lbs
(4)	Desired weight of cement—7½ bags × 94 lb/bag	705 lbs
(5)	Gross weight of truck, gravel, and cement (3) + (4)	24,515 lbs
(6)	Desired weight of sand	1,500 lbs
(7)	Gross weight of truck and materials (5) + (6)	26,015

Thus, gravel is added until the scales indicate a gross weight of 23,810 pounds, cement is added until 24,515 pounds are indicated, and sand is added until the total is 26,015 pounds.

Each truck should be weighed before each load. The greatest source of error in this method is the weight changes caused by men getting on and off the scales during weighing. One man stepping on the scales during the addition of cement can cause a shortage of about two bags in the batch. The materials can be loaded with a conveyor, clam shell, or bucket loader.

b. Measurement by Volume. The measurement of aggregate by volume for paving operations is usually an expedient method because of the low efficiency and accuracy. Essentially, known weights of materials are placed in a wheelbarrow, bucket, or box. The surface is leveled and the weight marked on the inside. This is repeated until the desired weights are marked. The major error in this method is caused by the differences in the amount of voids in each batch. Different unit weights for each item make it necessary to have a separate measuring container for each mix component.

275. Truck Requirements

The condition of the haul road and any authorized increases in truck capacity will affect the number of batches that can be hauled per truck. For round trips of 4 to 10 miles over roads in fair condition, trucks can average 10 miles per hour, including loading and dumping, if cement from sacks is handled at a dock; 12 miles per hour if bulk cement is batched. To determine truck requirements for round trip distances of 4 miles or more, the following formula may be used as a guide:

$$N = \frac{BD}{bs}, \qquad (15\text{–}1)$$

where: N = number of batch trucks required
B = number batches mixed per hour
D = round trip distance in miles, batch plant to paver (minimum of 4 miles)
b = number of batches per truck
s = speed in miles per hour (using 10 for sacked cement, 12 for bulk, increasing if D is more than 10 miles)

Section II. PROCEDURE

276. Sequence of Operation

Recommended sequence for concrete paving operations is listed below. Actual operation is discussed in paragraphs 277 through 294. See Appendix II for inspection checklist suggested as a guide for paving operations. Paragraphs 295 through 303 should be consulted prior to paving operations during hot or cold weather.

a. Preparing subgrade.
b. Preparing and transporting mix.
c. Preparing expansion joints.
d. Placing mix.
e. Vibrating.
f. Finishing surface.
g. Preparing contraction joints.
h. Curing.
i. Sealing joints.
j. Removing forms.
k. Testing surface.

277. Subgrade Preparation

a. Final Preparation. The subgrade is compacted and brought approximately 3 to 4 inches above grade. The surface is shaped and cut to 2 inches above grade with a motor grader. The forms (chap. 12) are set to line and grade. After the forms are checked, the final grading is done with the form-riding subgrader. The cutting blades should be carefully set so that they will cut to the correct depth. The subgrader should cut the grade within ¼ to ⅛ inch above the finished grade. The subgrade planer should cut the subgrade to the required section and elevation. The subgrade should be checked to see that it conforms to the required section within specified tolerances (usually ⅛ inch). A scratch template is used for checking the contour of the finished subgrade. The template is operated on the side forms and is provided with adjustable steel rods projecting downward to the subgrade at not less than 1-foot intervals (fig. 101). The rods are adjusted to the required contour of the subgrade and the subgrade checked. If necessary, material should be removed or added (as required) to bring all portions of the subgrade to the correct elevation. It should then be thoroughly recompacted and retested with the template. The equipment should be of such strength and rigidity that it will not show a deflection of more than ⅛ inch at the center. If no template is available, the subgrade may be checked by using a piano wire or other strong line to mark the grade. The wire is held taut at the top of the form which has been set to grade, and meas-

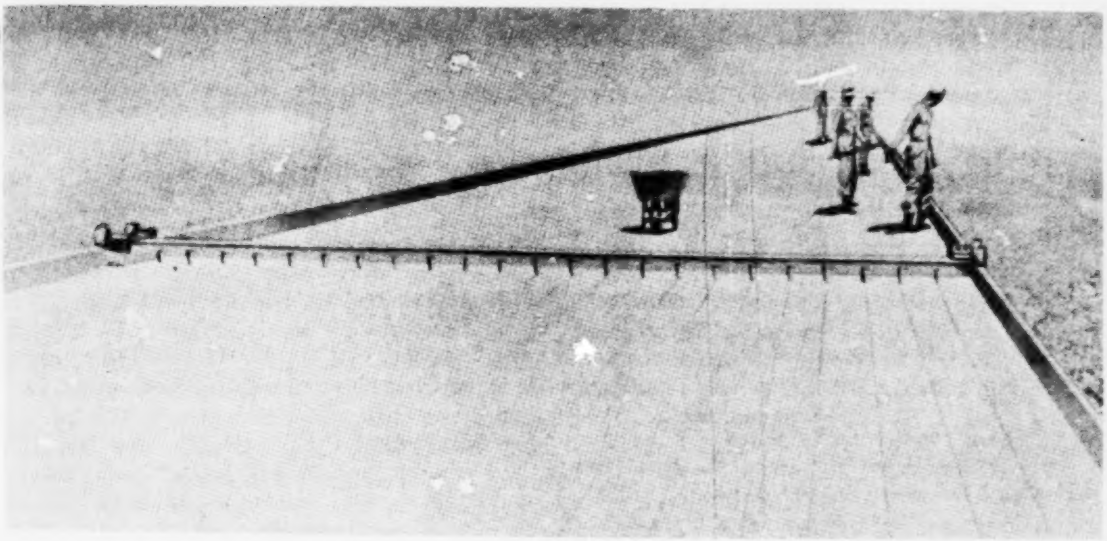


Figure 101. Checking subgrade with scratch template before placing concrete.

urements are made from the wire to the subgrade at intervals of about 1 foot.

b. Wetting Subgrade. To minimize absorption of moisture from the concrete by the subgrade, the subgrade should be in a moist condition when the concrete is placed. The subgrade should be thoroughly wetted sufficiently in advance of placing the concrete to assure that the surface will be damp, but not muddy. In dry, hot weather, the subgrade should be sprinkled just ahead of the placing and spreading operations (fig. 102). The degree of saturation will depend on the character of the material in the subgrade, and the sprinkling must be controlled accordingly. Soft or spongy places in the subgrade should be corrected by removing the poor material and replacing with good material, which should be thoroughly compacted. The subgrade is given the final rolling with a 5- to 8-ton or a 10-ton roller, depending upon the abrasiveness of the subgrade. Some type of soil, such as loess, will absorb water like a sponge. When wet, it is soft and when dry it will cause plastic shrinkage due to water loss from the concrete. A layer of tar paper placed on the subgrade is the best method of circumventing this problem. Bituminous treatments work in some cases, but worsen conditions in others. If a bituminous treatment is to be used to check this water loss, a test section should be used.

278. Mixing

a. Preparation. Mixing is one of the most important steps in producing high quality concrete that will meet design specifications. For efficient production of concrete, the correct type of mixer should be selected, the location of the mixer and ingredients should be convenient to paving operations, and the mixer should be operated properly. The mixing of concrete may be done in stationary mixers in a central plant combining the batching and mixing operations or in pavers at the site of the work. Regardless of the type of mixer used, the materials should be blended into a uniform mix throughout the batch with all aggregate particles well coated with the paste and the mixed concrete should be discharged without segregation or loss.

b. Inspection. All concrete mixing units should be checked to see that they are clean and in good operating condition. The mixing blades should not be worn excessively. Blades worn down about ¾ inch or more should be replaced with new blades. The water batching mechanism should show no leakage of water when the valve is closed. It is especially important to check for water leakage. All devices for controlling the mixing of the concrete should be checked for proper operation. Automatic equipment for batching and dispensing admixtures should also be checked for satisfactory operation if applicable.

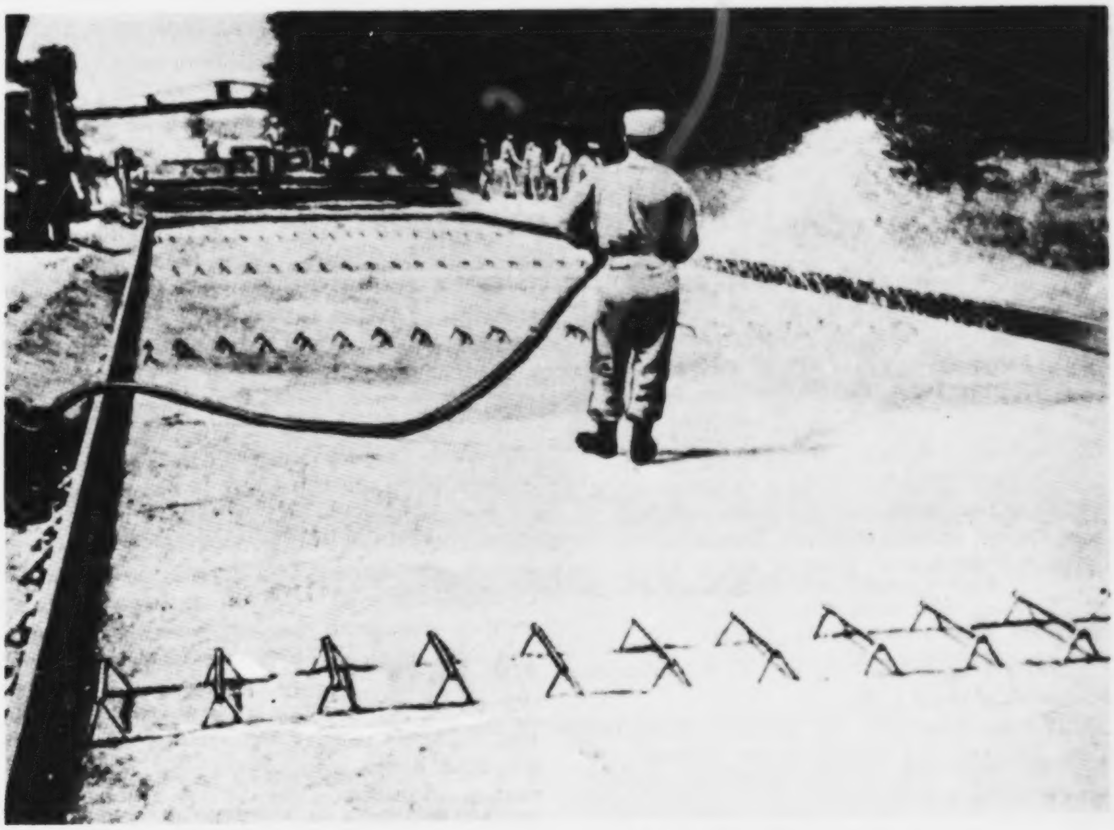


Figure 102. Final sprinkling of subgrade.

c. Pavers. Pavers usually are used for large-scale paving operations. The aggregate and bulk cement, when used, are weighed at the batching plant and hauled to the paver in batch trucks. Bagged cement usually is added just before the concrete is mixed (where and when it is added depends on the situation). This cement may be added to aggregate in the trucks after they arrive on the job or after the aggregate is unloaded into the mixer skip pan. The water is added to the batch during charging of the aggregate and cement into the mixer.

(1) Pavers are equipped with a boom and bottom dump bucket to distribute the mixed concrete between the forms. This equipment should be checked to see that it is in good operating condition. The discharge gate on the bucket should close tightly so that there will be no leakage of mortar or concrete.

(2) Dual drum pavers normally are used for pavement construction. With these pavers, the concrete is partially mixed in the first drum into which the materials are charged and mixing is completed in the second drum into which the partially mixed concrete is transferred during the operating cycle.

d. Central Plant Mixing. Central plant mixing permits closer coordination of the batching and mixing operations, and provides the best conditions for inspection and control of the mix. However, this type of mixing plant is less flexible than the use of pavers, and requires additional equipment and labor for transporting and distributing the concrete in the forms. When a central plant is used, all of the materials generally are batched by weight. Central plants are discussed in greater detail in paragraphs 257 through 260.

279. Transporting the Mix

a. Precautions. After it leaves the mixer, the concrete must be handled and transported in such a manner that segregation of the concrete does not occur. Improper handling and transporting can spoil the most carefully designed and properly mixed concrete. Segregation occurs because concrete is composed of materials of different particle sizes and specific gravities. The coarser aggregate particles in a concrete mix placed in a bucket tend to settle to the bottom and the liquid mix rises to the top. This is one cause of honeycomb concrete or rock pockets.

b. Dump Trucks. Dump trucks are the most commonly used method of transporting plastic concrete on large projects (central mix plant) in theaters of operation. The hauling distances must be kept as short as possible because segregation occurs rapidly enroute. Segregation can be minimized by preparing as stiff a mix as possible and adding an air-entraining agent to the mix.

c. 34E Paver. The 34E paver (para 238) is capable of transporting its own concrete mix from the mixer drum to the grade where it is to be distributed as shown in figure 103. This is accomplished by a bucket which is suspended from the boom on four rollers, and is pulled back and forth on the boom with two bucket ropes. The bucket doors are opened by a lever movement from the operator's platform and are closed automatically when the bucket returns to its position under the discharge trough. The bucket has a spreading radius of 32 feet 6 inches.

d. Belt Conveyors. For transporting concrete short distances, or on slopes of not more than ½ inch per foot upward, or 1 inch per foot downward, belt conveyors may be used if available and if the work of setting them up is justified by the volume of concrete to be moved. Belt conveyors are used more frequently for moving aggregate or cement (either in sacks or in bulk), but wet concrete can also be carried directly on the belt. The belt is usually 12 to 60 inches wide, up to several hundred feet long, supported at intervals of 4 to 5 feet by V-type idler pulleys, and can be operated at speeds up to 400 linear feet per minute. The

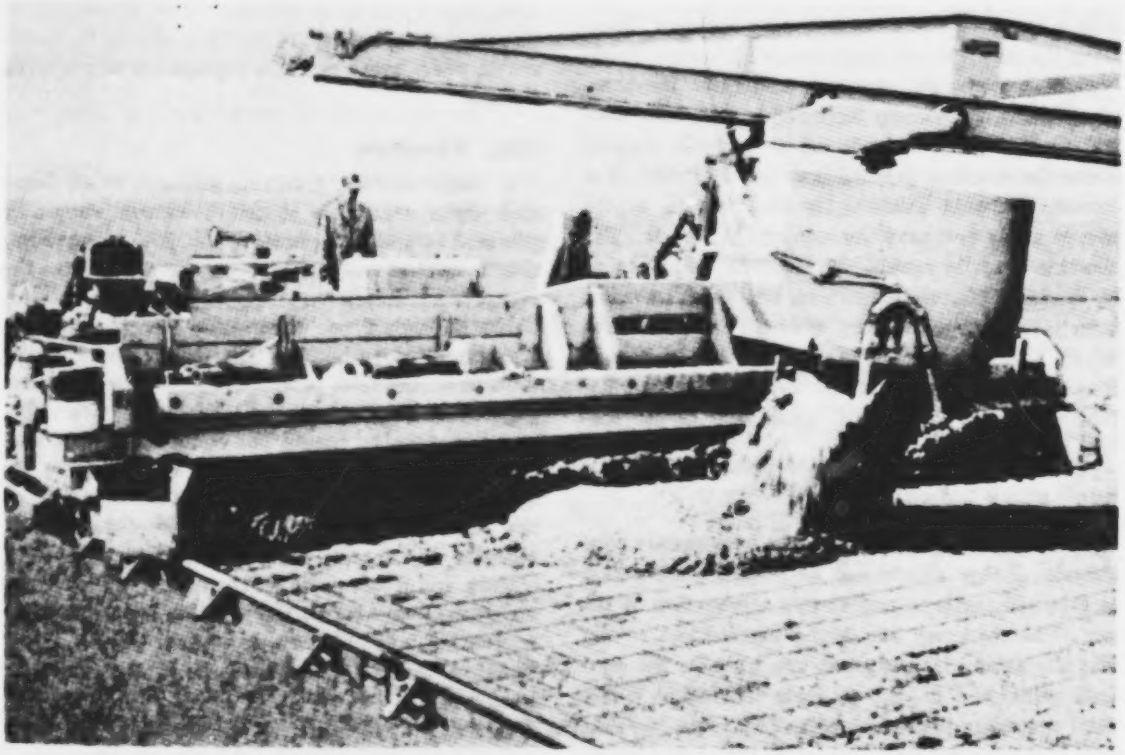


Figure 103. Placing concrete with 34-E paver and spreader.

belt is used to handle a continuous flow of concrete, as from a hopper, or to handle the intermittent output of a batch mixer. The belt is cleansed or wetted during its return trip to avoid an accumulation of dried mortar.

e. Nonstandard Equipment. Transit mixers, "Dumpcrete," and agitator trucks (paras 248–249) are designed to transport concrete mixes. These items are not standard Army equipment.

280. Placing Expansion Joints

Before the mix is placed, expansion joints should be constructed on the finished subgrade (para 270).

281. Concrete Placement

As discussed in paragraph 276*b*, the subgrade should be sprinkled far enough in advance of paving so that it will be in a moist condition, but not muddy (if possible, watering should also be accomplished the night before paving). The concrete should be deposited as nearly as possible to the placement site so that it will require a minimum of rehandling in the form. To avoid segregation, the concrete should not have a free fall of more than 3 to 5 feet. The most satisfactory means of handling the concrete into the forms is by bottom dump buckets of sufficient capacity to handle the complete batch of concrete from the mixer. The concrete is spread and struck off to a depth slightly above the required finished grade so that when it is consolidated and finished, the slab will be at the proper grade and have the required thickness. The concrete may be spread by concrete spreaders or by hand. Concrete spreaders are used on most large jobs as they are very efficient and save much labor. These spreaders are set so that they will strike off the concrete to the desired elevation for placing welded wire fabric (para 305) or for surface finishing.

282. Hand Spreading

Hand spreading should be done with square edge shovels. Rakes should not be used for spreading, as this will result in undesirable segregation of the mix. The workmen should be careful not to dig into the subgrade, and must not walk in the concrete with mud or dirt on their footwear. Where hand spreading is used, a strike-off is still required to level off the concrete surface at the proper elevation.

283. Placement at Joints

Concrete should not be dumped directly on or against the joints, but should be hand placed to avoid displacing the joint filler or load transfer assembly. The concrete should be deposited near the joint and then shoveled against both sides of the joint simultaneously to maintain equal pressure on both sides. The position of the joint and dowels should be continuously checked to see that there is no displacement.

284. Successive Layers

Concrete is spread in even layers from 6 to 24 inches in depth, depending on the type of construction. When placed in two or more layers, the sequence of operations precludes exposing a portion of any layer for more than 30 minutes as this may cause the formation of a plane of weakness between layers. The placing operation shown in figure 103 consists of two layers with welded wire fabric between them.

285. Honeycombing

To prevent honeycombing or voids in the concrete, the concrete is vibrated after placement as described in paragraph 286. Care should be taken not to overvibrate to avoid segregation and a weak surface.

286. Vibration

a. Requirements. Concrete adjacent to all forms and joints, regardless of slab thickness, should be vibrated by internal vibrators (fig. 104). The vibration is applied only long enough to consolidate the concrete and excessive vibration should be avoided. Vibrators should not be dragged through concrete, but should be withdrawn from the concrete during movement between points of vibration. Concrete adjacent to joints should be vibrated very carefully and the vibrator should not come in contact with the joint or load transfer material. Vibrators are operated only when necessary for consolidation of the concrete and should not be operated in the concrete during slack periods. Additional vibrators, motors, and repair parts for the vibratory equipment should be available on the job at all times in order to avoid delays or shutdowns of the paving operations in case of a breakdown of the vibrating equipment.

b. Surface Vibration.

(1) Internal vibration of the concrete slab is generally not necessary when the pavement

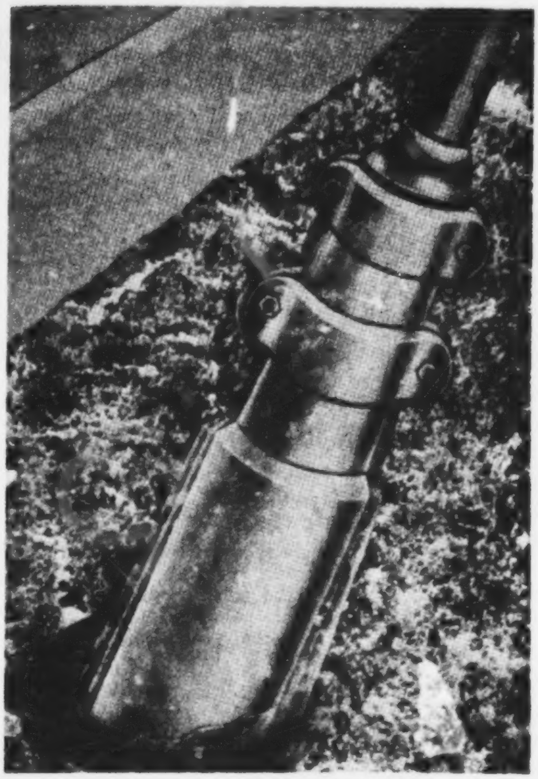


Figure 104. Internal vibration of a concrete mix.

is less than 12 inches thick. Consolidation and compaction of this concrete is dependent on the action of the finishing operations. Surface vibration may be required, in which case the finishing machine is equipped with a vibrator to apply high-frequency vibration to the surface of the concrete. If a vibrator is mounted on the finisher, it is mounted between the two screeds. This vibrator will not normally be used if the vibrator on the concrete spreader is being used. Surface vibration should be very carefully checked and should not be used except for very dry mixes.

(2) Vibration of more plastic mixes and overfinishing will accumulate an excessive layer of mortar of high water content at the surface, and will reduce the quality of the concrete at the surface where highest quality is necessary to withstand weathering. Excessive scaling and deterioration of pavements contribute to overmanipulation of the surface.

c. *Internal Vibration*. Concrete slabs, 12 inches or more thick, are vibrated by internal vibrators. Two types of vibrating machines are used for this purpose; one equipped with multiple unit vibrators, and the other having submersible vibratory tubes. Both the multiple vibrator machine and the vibrating tube machine tend to produce some segregation of the concrete in the region of operation. Care should be taken to avoid overvibration, and the vibrators should not be operated in one loaction in the concrete for more than 20 seconds.

(1) The multiple unit machine consists of a group of internal vibrating units mounted in a single line on a frame that is capable of perpendicular and radial movement. The spacing of the vibrating units on the frame should not be more than 30 inches. The multiple unit is generally attached to the rear of the concrete spreader and the concrete is vibrated directly after the spreading operation. In the operation, the vibrators are inserted in the concrete to within about 2 inches of the subgrade and dragged through the concrete as the spreading machine advances. A more satisfactory arrangement is to have the vibrating machine mounted on a separate carriage with provisions for withdrawal of the vibrating units from the concrete while the machine is advanced in steps of about 2 feet.

(2) The vibratory tube machine consists essentially of vibrating elements embodying two closely spaced parallel tubes, with a submersible vibratory motor mounted on each element. The tube assemblies are mounted on each element. The tube assemblies are mounted on a frame which may be attached to the spreader or finishing machine. The vibratory tubes should be readily adjustable to operate at any desired depth within the concrete. Usually, the vibrating tubes will be operated at approximately the midpoint of the slab thickness.

287. Finishing

Finishing operations are started immediately after placement of the concrete. The sequence of operations is as follows: spreading, transverse (machine) finishing, longitudinal (machine) finishing (if necessary), hand finishing and floating, straightedge finishing, burlap-drag finishing, and finally the edging of joints. Machine finishing is used except in places inaccessible to the machine where hand finishing is done. Finishing equipment and tools should be clean and free from hardened concrete or grout. As soon as concrete is placed, it should be accurately struck off and screeded to the crown and cross section and to such elevation that when properly consolidated and finished, the surface of the pavement will be free from porous places and will be at the correct grade.

a. Spreading. The concrete spreader (fig. 75) follows immediately behind the paver and works the intermittent batches of concrete into a continuous, uniform slab of concrete between the forms. The trolley blade, which is the first part of the spreader to come in contact with the wet concrete, moves transversely between the forms while the spreader advances forward on the forms. The trolley blade can be set at, below, or above the elevation of the top of the forms which facilitates the laying of two lifts of concrete for reinforcing material. The strikeoff plate strikes off the concrete at the desired elevation at, below, or above elevation of the forms and can be set to give the pavement a crown, a warp, or a straight cross section. The spreader works just in advance of the finishing machine which finishes the surface of the slab to the desired contour.

(1) The spreader operator, aside from the purely mechanical handling of the machine, must carefully watch the operation of the paver and learn by experience the best way to have the paver operator deposit the successive batches of concrete in front of the spreader.

(2) The spreader operator must also watch very carefully the action of the concrete in front of the screed of the finishing machine in order to make sure that he is not allowing too much concrete to go through for successful operation of the finisher and also that he is not striking the concrete off so low that the finishing machine screeds are starved.

b. Transverse Finishing. Finishing of the slab to the desired contour normally is accomplished by the transverse finisher (para 242). Before the machine is started for operations, be sure all adjustments are made and all accessory equipment is in working order. The crown adjustment will be made in accordance with the job specifications. In starting the finishing operation, place concrete against the bulkhead slightly higher than the forms. Lower the front screed so that the front edge of the screed is about in line with the front edge of the bulkhead. Start the finisher forward with the screed oscillating. As soon as the rear screed reaches the bulkhead, lower it to the form and run it a short distance to test the operation. If the finisher is operating back of a concrete spreader, be sure the spreader leaves enough material so that a full load can be picked up by the finisher. Two passes are required in most cases, to complete a finishing operation. The second pass should be delayed as long as possible so the concrete may settle before the final finishing is done. At the end of each day's paving, the operation will usually be finished at a bulkhead similar to the one at which it started. Care should be taken when coming over this bulkhead so that it is not forced out. It is best to lift the screeds slightly just as they begin to pass over.

c. Longitudinal Finishing. The small irregularities in grade are removed with the longitudinal finisher (para 251). The transverse guide mechanism is set to the same contour as that of the transverse finisher. The 12-foot float on the longitudinal finisher removes minor irregularities and score marks. This machine is used on high speed roads and airfields where small surface bumps would be noticeable. If enough skilled men are available to use straightedges, this finisher can be eliminated on most projects.

d. Hand Finishing and Floating. After transverse finishing, areas that were inaccesible to the concrete finishing machine are floated by hand by wooden hand floats or trowels. Floating by hand is accomplished from bridges resting on the side forms and spanning, but not touching, the concrete (fig. 105).

e. Straightedge Finishing. After hand floating is completed, but while the concrete is still plastic, minor irregularities and score marks in the pavement should be eliminated with long handled wooden floats and straightedges. The long handled floats may be used to smooth and fill in open-textured areas in the pavement surfaces, but the final finish should be made with the straightedge. Straightedges, 12 feet in length, may be operated from bridges and from the side of the pavement. A straightedge operated from the side of the pavement should be equipped with a handle, 3 feet

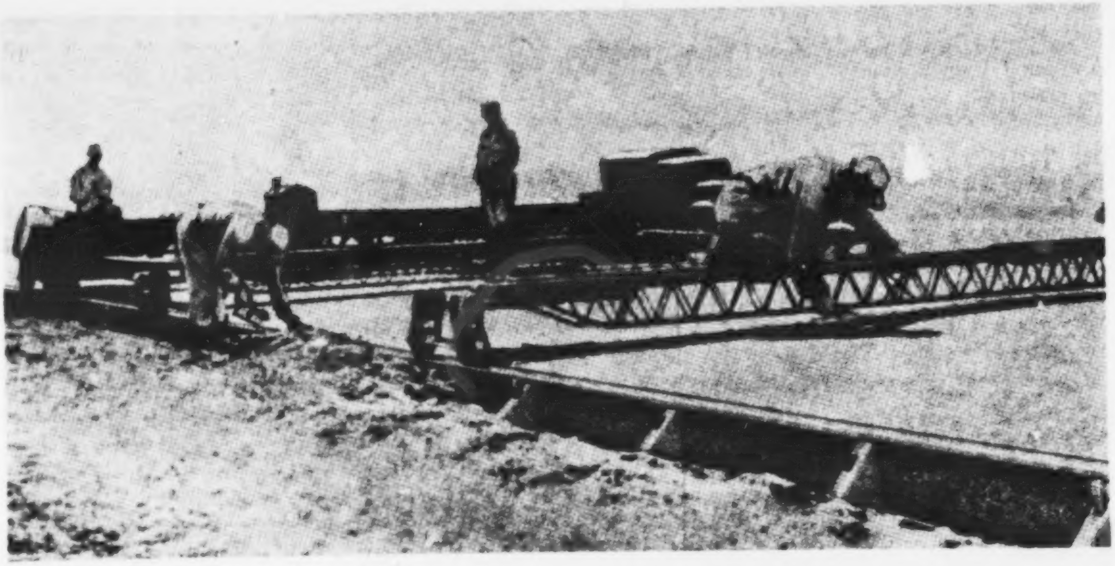


Figure 106. Hand finishing.

longer than one-half the width of the pavement, as shown in figure 106. The surface should then be tested for trueness with a 12-foot straightedge held in successive positions parallel and at right angles to the centerline of the pavement. The entire surface should be checked as necessary to detect any variations from the desired cross section. Depressions should be immediately filled with freshly mixed concrete, struck off, consolidated, and refinished.

f. Burlap-Drag Finishing. When most of the water glaze or sheen has disappeared and before the concrete becomes nonplastic, the surface of the pavement should be dragged longitudinally in the direction of the concrete placement, with a multiple-ply burlap drag at least 3 feet in width and equal in length to the width of the slab, as shown in figure 107. The leading transverse edge of the drag should be securely fastened to a traveling bridge, leaving at least 1 foot of the burlap adjacent to the rear edge in contact with the pavement. The drag is operated with the burlap moist. The burlap should be cleaned and changed as required. The dragging produces a finished surface having a fine granular or sandy texture without leaving disfiguring marks. The surface of the pavement at joint edges is dragged as necessary with a small hand-operated drag following edge tooling. No tool marks of any kind should be present on the finished surface.

288. Placing Contraction Joints

Contraction joints are constructed on the finished surface to provide a weakened plane to control cracking from construction (para 270).

289. Final Edging

After burlap dragging has been completed, the edges of slabs along the forms and at the joints should be carefully finished with an edging tool to form a smooth rounded surface of the required radius. Prior to final edging, any soupy mortar along the edges and any areas without sufficient mortar for obtaining good solid edges should be removed and filled solidly with concrete of correct proportions and consistency. Toolmarks should be eliminated, and the edges should be smooth and true to line. After removal of the forms, honeycombed or damaged areas should be patched.

290. Curing

Concrete should be cured by protection against loss of moisture and rapid temperature changes for a period of not less than 7 days from the beginning of the curing operation. Unhardened concrete should be protected from rain and flowing water. All equipment needed for adequate curing and protection of the concrete should be on hand and ready to install before actual concrete placement begins. In all cases in which the curing medium requires

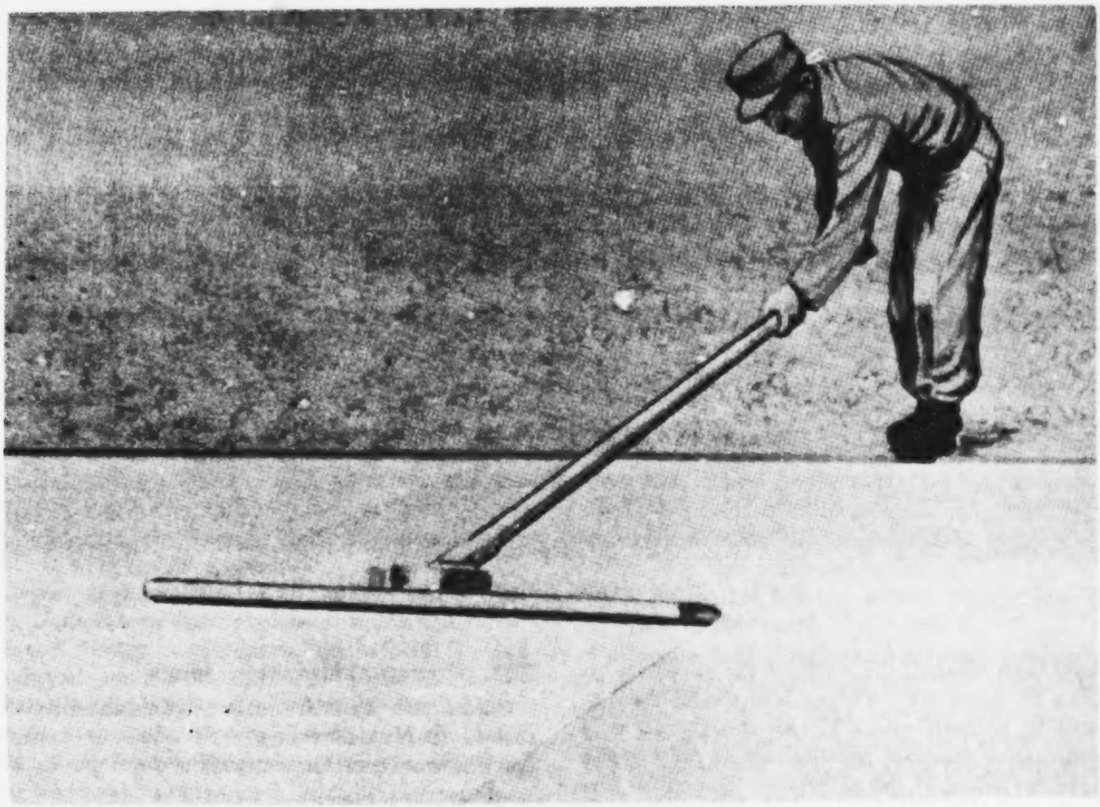


Figure 106. Finishing concrete with a straightedge.

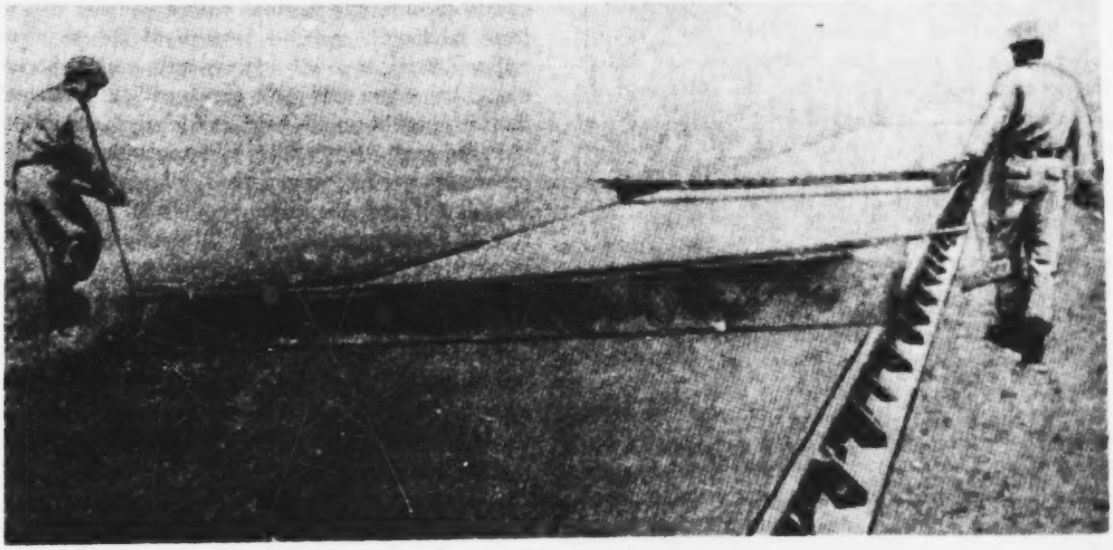


Figure 107. Burlap-drag finishing.

the use of water, the curing should have prior right to all water supply or supplies. Protection should be provided as necessary to prevent cracking of the pavement caused by temperature changes during the curing period. The sides of concrete slabs exposed by the removal of forms should be protected within 1 hour after removal of forms to provide the exposed surfaces with continuous curing treatment equal to that provided by the method selected for curing the slab surface, and to prevent injury to the pavement edges and the underlying subgrade. Covering material should not be used that contains or becomes contaminated with sugar in any form, tannic acid, or any other substance detrimental to portland cement concrete. Any covering material such as mats, waterproof paper, or impermeable sheets used in curing should be removed as necessary for testing the surface, correcting deficiencies, and sawing joints. The concrete surface should be maintained wet with a water spray until the covering materials are replaced. Where membrane curing is used, all damaged areas should be resprayed with curing compound immediately upon completion of testing and any required surface correction.

a. Initial Curing. Immediately after the finishing operations have been completed and the concrete has set sufficiently to prevent marring the surface, the forms and entire surface of the newly laid concrete should be covered with wetted burlap or cotton mats as discussed in *c* below. The initial moist curing is continued for a period of not less than 24 hours. The surface of the newly laid concrete must be kept moist until the burlap or cotton-mat coverings are in place.

b. Final Curing. Curing of the concrete is continued for the duration of the required curing period by any of the methods described below.

c. Burlap or Cotton-Mat Curing. The coverings may be either burlap or cotton mats. Burlap covers consist of two or more layers of burlap having a combined weight of 14 ounces or more per square yard in a dry condition. Burlap should either be new or have been used only for curing concrete. Cotton mats and burlap strips should have a length, after shrinkage, at least 1 foot greater than necessary to cover the entire width and edges of the pavement lane. The mats should overlap each other at least 6 inches. They should be thoroughly wetted before placing and kept continuously wet and in intimate contact with the pavement edges and surface for the duration of the required curing period.

d. Waterproof-Paper Blankets or Impermeable Sheets. Immediately after removing the covering used for initial curing, the surface of the concrete should be wetted with a fine spray of water and then covered with waterproof-paper blankets (fig. 108). Polyethylene coated burlap blankets or polyethylene sheets are used if available. The burlap of the polyethylene coated burlap should be thoroughly saturated with water before placing. The waterproof-paper blankets, polyethylyene coated burlap blankets, or polyethylene sheeting should be in pieces large enough to cover the entire width and edges of the slab. (Polyethylene sheets carefully lapped will eliminate the necessity for two curing treatments. This material is also lighter, cheaper, and more easily handled than polyethylene coated burlap.) The sheets should be placed with the light-colored side up. Adjacent sheets should overlap not less than 12 inches with the lapped edges securely weighted down and cemented or taped to form a continuous cover and a completely closed joint. The coverings must be adequately weighted down to prevent displacement or billowing from winds. Covering should be folded down over the side of the pavement edges and secured by a continuous bank of earth or other approved means, as shown in figure 108. Tears and holes appearing in coverings during the curing period must be patched immediately. The coverings should remain in place during the entire specified curing period.

e. Membrane Curing. Immediately after removing the wet covering used for initial curing, the entire exposed surface of the concrete should be uniformly coated with a pigmented membrane curing compound. The curing compounds are either wax or resin-base. The concrete should not be allowed to dry out before the application of membrane. If any drying has occurred, the surface of the concrete should be moistened with a spray of water.

(1) The curing compound is applied to the finished surfaces by an approved automatic spraying machine (if available) as soon as the free water has disappeared. The spraying machine should be self-propelled and ride on the side forms or previously constructed pavement, straddling the newly paved lane. The machine should be equipped with spraying nozzle or nozzles that can be so controlled and operated as to completely and uniformly cover the pavement surface with the required amount of

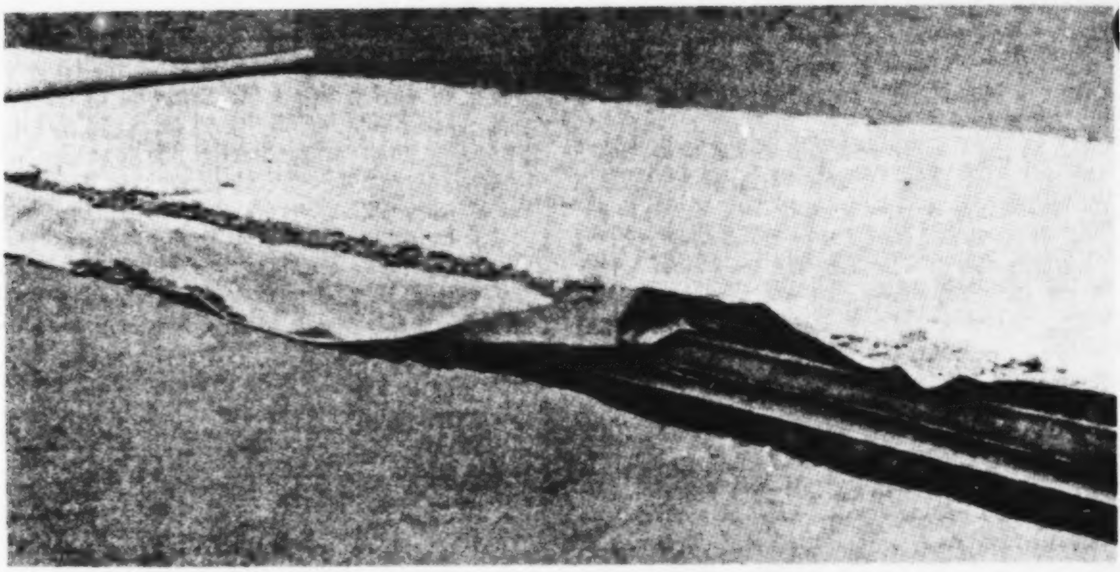


Figure 108. Waterproof curing paper used after burlap curing.

curing compound. The curing compound in the storage drum used for the spraying operation should be thoroughly and continuously agitated mechanically throughout the full depth of the drum during the application. Air agitation may be used only to supplement mechanical agitation. Spraying pressure should be sufficient to produce a fine spray and cover the surface thoroughly and completely with a uniform film. Spray equipment must be maintained in first-class mechanical condition and the spray nozzle should be provided with an adequate wind guard. The curing compound should be applied with an overlapping coverage that will give a two-coat application at a coverage of not more than 200 square feet per gallon for both coats.

(2) The application of curing compound by hand-operated pressure sprayers is satisfactory only on odd widths or shapes of slabs and on concrete surfaces exposed by the removal of forms, as authorized. When application is made by hand-operated sprayers, the second coat is applied in a direction approximately at right angles to the direction of the first coat. The compound should form a uniform, continuous, cohesive film that will not check, crack, or peel, and be free from pinholes and other imperfections. If discontinuities, pinholes, or abrasions exist, an additional coat should be applied to the affected areas within 30 minutes. Concrete surfaces that are subjected to heavy rainfall within 3 hours after the curing compound has been applied should be resprayed.

(3) Necessary precautions should be taken to assure that the concrete is properly cured at the joints, but that no curing compound enters the joints that are to be sealed with joint-sealing compound. The top of the joint opening and the joint groove at exposed edges should be tightly sealed as soon as the joint-sawing operations have been completed. After application of the seal, the concrete in the region of the joint should be sprayed with curing compound. The method used for sealing the joint groove is also effective in preventing loss of moisture from the joint during the entire specified curing period.

(4) Approved standby facilities for curing concrete pavement should be provided at a location readily accessible to the site of the work. These would be for use in the event of mechanical failure of the spray-

ing equipment or any other conditions that might prevent correct application of the membrane-curing compound at the proper time.

(5) Concrete surfaces to which membrane curing compounds have been applied should be adequately protected for the duration of the entire curing period from pedestrian and vehicular traffic, except as required for joint-sawing operations and surface tests, and from any other possible damage to the continuity of the membrane. Any area covered with curing compound that is damaged by subsequent construction operations within the curing period must be resprayed.

291. Sealing Joints and Cracks

Joint sealing is discussed in paragraph 271. All random cracks must be grooved and sealed. The top of the crack is grooved to a depth of 1 inch and to a width of not less than 1/4 inch, nor more than 5/8 inch with a mechanical grooving machine. The top of the crack is widened without spalling or otherwise damaging the concrete. All loose and fractured concrete should be removed and the groove thoroughly cleaned and completely filled with suitable joint-sealing compound.

292. Removal of Forms

Forms should be removed for reuse as soon as the concrete can support itself, unless the forms are used to promote curing. The usual time of removal is from 1 to 3 days after placement. In cold weather, they are left on up to 7 days.

293. Surface Test

The finished surface of the pavement should be tested with a 10-foot straightedge for trueness after curing has been completed. The straightedge is operated in different positions to reveal any irregularities. Deviations from specification requirements should be corrected, or the pavement removed and replaced. Minor irregularities can usually be corrected by grinding the surface. A nonstandard rolling straightedge is shown in figure 109.

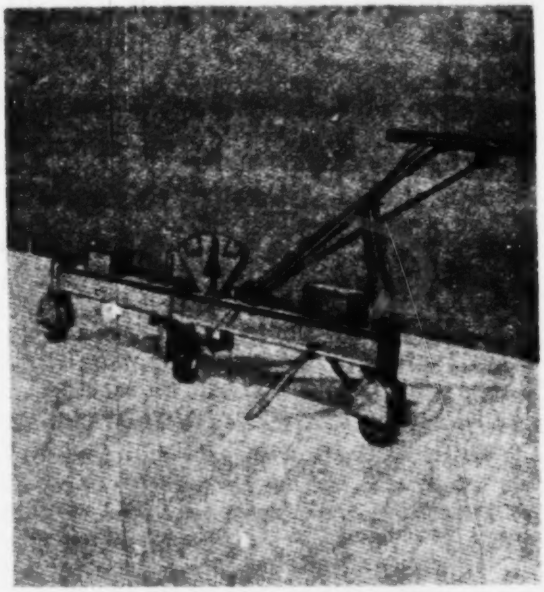


Figure 109. Nonstandard rolling straightedge.
From "Concrete Pavement Inspector's Manual," courtesy of Portland Cement Association.

294. Strength Tests

During construction of the pavement, tests should be made of the flexural strength of the pavement to assure conformance with design criteria. Tests are usually made at 7 and 28 days and more frequently if necessary. If the required strength is not obtained, the mix should be adjusted or the thickness of the pavement increased. See TM 5–530.

Section III. COLD AND HOT WEATHER TECHNIQUES

295. Cold Weather Construction

Concrete construction at temperatures lower than 30° F. normally requires additional equipment and protective material. At temperatures above 30° F., concrete can be placed using standard equipment and methods. The following techniques are recommended for constructing pavement during cold weather:

a. Prepare, treat, and protect the subgrade.

b. Produce and deliver concrete at temperatures compensating for heat loss during placement so that it will harden at a normal or accelerated rate.

c. Place and finish the slab with a minimum loss of heat from the concrete.

d. Protect the slab to maintain satisfactory hardening temperatures.

296. Frozen Subgrade

a. Preparation. If concrete is placed on subgrade which is frozen, much heat will be withdrawn from the concrete so that its rate of hardening will be retarded. If the frost extends in the subgrade for a considerable depth, it may withdraw sufficient heat to freeze at least the lower part of the slab. It is important, therefore, that the subgrade be almost or completely free from frost. Whenever possible, it is best to prevent the freezing of the subgrade.

(1) Except in unusually protracted cold spells, freezing may be prevented by covering the grade with straw. Prior to freezing temperatures, a thickness of 12 to 24 inches is recommended, depending on the temperature expected. Since dry straw has better insulating properties than wet straw, it may be necessary to cover the straw with tarpaulins or waterproof paper.

(2) At the time of setting forms and fine grading, the rough grade is uncovered, finished, and the finished grade re-covered with straw and protected until just before concreting. If the finished subgrade becomes soft and muddy, all free water and mud should be removed and the subgrade brought to proper elevation by the addition of sand, screenings, gravel, cinders, or unfrozen earth, hardtamped or rolled to produce a firm grade. Heating this material before placement will give further protection to the concrete if concreting follows immediately or if the heat is retained by covering with straw until just before the concrete is placed.

b. Treatment of Frozen Subgrade.

(1) When the subgrade has become frozen, the surface layer may be thawed by burning straw on it, by using torches or steam, or where the grade permits, by covering the course with hot sand, screenings, or cinders. Burning straw covered with sand will remove frost to a depth of 8 inches or more. The straw is spread loosely upon the subgrade to a depth of 4 or 4½ feet (50 to 70 pounds per square yard). Flax straw is preferred, but any dry straw may be used; loose straw is better than baled straw. After the straw has been placed, sand is spread on it at the rate of 3½ or 4 cubic yards per 100 square yards (100 to 150 pounds per square yard) of subgrade, using pit-run sand, blow sand, or any other inexpensive sand available. This sand will ordinarily weight the straw down to about half the depth to which it was spread. The straw is then ignited at the edges. It will smolder for hours under the sand, which holds in the heat so that it is available for thawing the subgrade instead of being dissipated into the air. The thawed subgrade is then covered with fresh straw to hold the heat and prevent refreezing. This leaves a layer of granular material on the subgrade. This material may be left in place or, if necessary, may be removed during the fine grading or just ahead of the placement of concrete. When the depth of frost to be removed is only about 2 inches, the thickness of the straw may be reduced to 2½ or 3 feet (30 to 50 pounds per square yard) and the sand cover applied at the rate of 2½ or 3 cubic yards per 100 square yards (50 to 100 pounds per square yard) of subgrade.

(2) The surface layers of frozen subgrade may be thawed by surface heaters such as are used for patching and resurfacing asphalt pavements. A layer of hot sand or screenings spread on subgrade which has frozen to only small depths may be satisfactory for removing the frost. Where the grade permits, these blanket courses may be left in place to provide an insulating course between the concrete and any frost which may be left in the subgrade. The thickness of heated materials required will depend on the depth to which the frost has penetrated. A 1-inch layer may be sufficient when the frost has penetrated slightly, while for greater penetrations a 3- or 4-inch layer may be required. A large volume of materials will be needed for these greater thicknesses and the method probably will not be economically practicable except when a suitable material is locally available at low cost. These granular materials may be heated in a sand-dryer unit similar to that used by a portable or stationary asphalt plant. Such a unit can produce enough sand to cover

the subgrade ahead of one concrete paving mixer, heating the sand to 400° or 450° F.

(3) Concrete should not be placed immediately upon material of this temperature (400° to 450° F.); rather, the heated material should be spread and covered with straw the day before concrete is to be placed. By the time of concreting, the subgrade will have been thawed by the heat of the granular material, the temperature of which will have been reduced to a safe point. At the time of concreting, the temperature of the sand should not exceed 90° F.

(4) It is unnecessary to remove frost to its full depth from subgrade soils which do not have appreciable volume change under frost action, provided there is a layer of frost-free material insulating the concrete from the frozen subgrade soil. This is particularly applicable where granular subbases are being used. The thickness of the unfrozen insulating layer depends upon the depth of the frost which underlies it. The required thickness should be determined by methods given in TM 5-330.

297. Effect of Temperature

The rate at which concrete hardens and gains strength is retarded by low temperatures and accelerated by high temperatures. Near the freezing point the rate is very slow and at temperatures below freezing there is almost no increase in strength. Concrete which has been kept at a low temperature for a period will later gain strength more rapidly when more favorable conditions are provided. To secure good results, the temperature of concrete when placed should be high enough for the concrete to harden; the concrete should then be kept at a suitable temperature until it has gained ample strength. These requirements may make it necessary to heat the concrete ingredients and to protect the concrete against low temperatures.

298. Heating Materials

If the aggregate is at a temperature above 50° F., it will usually be necessary to heat only the mixing water. If the mixing water is heated much above 175° F., there is danger of flash setting. When the aggregates are below about 47° F. and it is desired to produce a concrete temperature of 70° F. or more, the aggregates also must be heated.

a. Mixing Water. The heated mixing water should never be placed in direct contact with the cement; it should be added to the aggregates to provide an opportunity for distribution of the heat before the cement is added.

b. Aggregates. Aggregates are more difficult to heat than water and special equipment will be required to heat them in the quantity needed to operate a paving mixer. Usually, it will be possible to produce concrete of the required temperature by heating only the sand, but if the coarse aggregate contains frozen lumps, it must be heated also. The use of steam is a practicable method of heating aggregate. Closed steam coils are preferable to open jets because of the problem of moisture control in the aggregate. However, they require larger storage piles or bins than those needed when live steam is used, because transfer of heat is slower. Live steam may be fed into the base of stockpiles which have been covered with tarpaulins. Further increases in temperature can be attained by discharging the steam through the aggregates in the bins above the weighing hoppers. Best results are obtained when the bins are kept well filled and batches are loaded out at a uniform rate. In using live steam, it is better to use steam under considerable pressure. Use of live steam at low pressure is more likely to result in the accumulation of condensed moisture. This may result in a variable moisture content of the aggregate which will require careful watching to avoid undesirable variations in the consistency of the concrete. This difficulty may be overcome if careful attention is given to control of the concrete's consistency.

c. Concrete. Oil-burning heaters can be used for heating concrete in the mixer. These inject a hot flame into the mixer drum. In relatively mild weather and on small jobls, they are sometimes used as the sole means for heating the concrete. At lower temperatures and on large jobs, however, they are effective only in producing an additional boost in temperature to that obtained by other methods.

d. Determination of the Amount of Heating. It is necessary to check on the amount of heating necessary to bring the mix up to the specified temperature. Assuming no ice is present in either the water or aggregate, this may be done by using figure 110 and the following formula:

$$X = \frac{(Wg \times Tg + (Ws \times Ts) + (Wc \times Tc)}{Wg + Ws + Wc} \qquad (15\text{–}2)$$

where: X = Weighted average temperature of aggregates and cement

T = Temperature of heated gravel (G), sand (S), or cement (C) in degrees

W = Weight of gravel (G), sand (S), or cement (C)

Temperatures must be increased until the concrete temperature is at the desired point.

Example: Determine the amount of heating necessary to place concrete at a mix temperature of 55°F. under the following conditions:

Material	*Weight*	*Temperature*
Gravel	2000	27
Sand	1200	27
Cement	600	40

Solution: The aggregate must be heated to above 32°F. to avoid contact freezing between the aggregate and water. As an additional safety factor, say it is planned to hea the aggregates to 35°F. Therefore,

$$X = \frac{(2000 \times 35) + (1200 \times 35) + (600 \times 40)}{2000 + 1200 + 600}$$

$$= \frac{70{,}000 + 42{,}000 + 24{,}000}{3800}$$

$$= \frac{136{,}000}{3800} = 35.8°\text{F. Say } 36°\text{F.}$$

From figure 110 the water must be heated to 137°F.

299. Heating Equipment

Heating equipment must be operated for some hours before paving starts. If a sand dryer is used to heat the aggregate, it should be started early so that an ample supply of heated sand is available when the mixer starts. Either provision should be made for heating, or an insulated bin should be provided for aggregates stored in the bins overnight or during shutdowns, to keep them from freezing. If steam heating is used, it will frequently be neces-

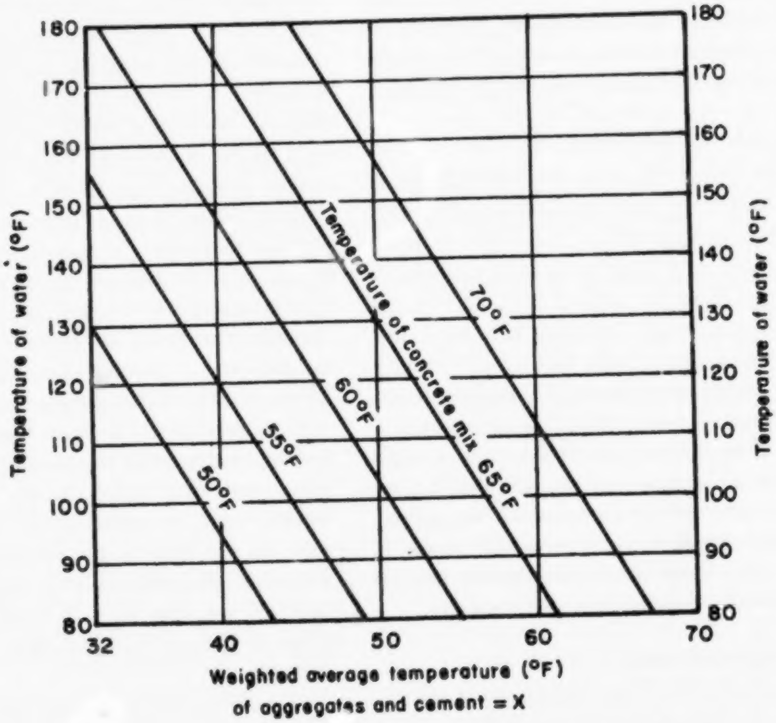


Figure 110. Mix temperatures versus component temperatures.
From "Construction of Concrete Pavement in Cold Weather," courtesy of Portland Cement Association.

sary to discharge live steam constantly into the covered stockpile throughout the entire 24 hours to assure an adequate supply of aggregate at the required temperature.

300. Maintaining Heat

In the construction of large areas of pavement at a comparatively short distance from the plant, such as is found in airport construction, a central mixing plant will often be found advantageous. The mix may be transported to the subgrade in dump trucks covered with tarpaulin. In a short haul from mixer to subgrade, the loss of heat will not be great and, with a little experience, the temperature at the mixer can be adjusted to obtain the desired temperature of concrete on the subgrade. In cold, windy weather, a piece of sheet metal may be placed over the mixer drum opening opposite the burner to reduce heat losses.

301. Placing and Finishing

The concrete should be placed and finished quickly in a manner which will result in minimum heat loss from the concrete. To facilitate speed in finishing, a minimum amount of mixing water is desirable. Special attention should be given to the design of a mix which will reduce bleeding to a minimum. Frequently this may be accomplished by increasing the amount of fine material in the sand or by making adjustments in the gradation or in the type of aggregates used. To accelerate the hardening of the concrete, calcium chloride may be added at the time of mixing in amounts not exceeding 2 pounds per sack of cement. This proportion applies when flake-type calcium chloride containing about 78 percent anhydrous calcium chloride is used; if the pellet type, which contains about 96 percent anhydrous calcium chloride, is used, the amount added to the concrete should not exceed about 1.6 pounds. Use of calcium chloride will permit more rapid finishing and allow the insulating layer of straw to be placed on the pavement sooner. Concrete which is too hot tends to harden quickly, materially slowing down the finishing operations. Concrete containing calcium chloride placed at a temperature in excess of 90° F. hardens too quickly to permit good results in finishing. When the temperature does not fall below about 15° F., finishing work may be completed in the open. If provision is made for quick application of straw and paper or cloth cover, no other special protection is necessary. At temperatures below 10° F., especially with strong wind, it is necessary for the finishers to work under some form of shelter. The shelter may be a covered framework mounted on wheels and rolled forward as work progresses. Enough room should be provided for men to work. If the shelter alone is not sufficient to reduce the heat loss as required, portable space heaters may be used. At very low temperatures, it may be necessary to heat steel side forms before the concrete is placed. Wooden forms have been used to advantage in winter.

302. Protection After Finishing

Ordinary curing specifications, which are aimed at supplying or retaining sufficient water within the concrete to assure continuing hydration of the cement, may be disregarded during cold weather. Water evaporates very slowly at low temperatures and the covering applied to protect the pavement from cold will be sufficient also to reduce evaporation and retain plenty of moisture in the concrete for curing.

a. Use of Straw and Steam Pipes. As soon as the concrete is sufficiently hard, a layer of dry straw should be applied promptly to the pavement. When necessary to apply straw before the pavement has hardened sufficiently to walk on without marring the surface, light, movable bridges may be used in applying the protective covering. From 12 to 24 inches of straw may be applied, depending on prevailing air temperatures. Since dry straw has better insulating properties than wet straw, it should, when necessary, be covered with waterproof paper or canvas to keep it dry. This will also keep wind from blowing away the straw, exposing portions of the pavement. In extreme conditions, steam pipes may be used under the covering to provide additional heat.

b. Equipment. Equipment other than hand forks for handling straw may consist of available pieces adapted to meet the need. Both baled and loose straw can be handled by a clamshell equipped with long teeth to convert it into a grappling fork.

c. Temperature. The heat of hydration increases the temperature after covering. While this increase in temperature cannot be relied upon as a substitute for heating materials, it will offset to some extent loss of heat during finishing. There is a substantial rise in the temperature of the subgrade after the warm concrete is spread. This quick rise in temperature indicates a possible danger of placing concrete on a frozen subgrade which upon thawing would have appreciable volume change during early hardening of the concrete. It is recommended that concrete be protected from freezing until it has attained a flexural strength of at least 400 pounds per square inch. The length of time for which protection is required will depend on the temperatures maintained and on the corresponding rate of hardening. It may range from 72 hours, for high-early strength concrete mixtures, to 7 to 10 days for normal concrete.

303. Hot Weather Construction

High temperatures of either the concrete or the air require adjustments in construction procedures if satisfactory results are to be obtained. An increase in the temperature of freshly mixed concrete results in an increase in the amount of mixing water needed to maintain the same slump. An increase in temperature from 73° to 120° F., while maintaining the same slump in a 5.5 sack mix, would result in the increase of 3.3 gallons of mixing water per cubic yard. Such an increase would lower the 28-day strength by approximately 10 percent.

a. Reduction of Mix Temperature. All reasonable efforts should be made to keep the mix temperature below 85° F.

(1) *Cooling mixing water.* The water supply may be protected from the heat of the sun by painting storage tanks with white or aluminum paint. Natural cooling by evaporation of moisture from burlap wrapped containers may be used on small projects. Utilization of existing underground storage (such as wells) and burying pipelines are examples of measures that may be taken under extreme conditions.

(2) *Sprinkling aggregate stockpiles.* In some extreme cases, the temperature of aggregates can be lowered by sprinkling th stockpiles. This not only lowers their temperatures by evaporation but also satisfies the absorptive qualities of the aggregate. The moisture content increase should be considered in the design of the mix.

(3) *Addition of ice.* The addition of flaked ice to the mix as part of the mix water works well, but ice will not be generally available in the necessary quantities in theater of operations construction.

b. Moist Curing. Maintenance of moisture near the surface in the concrete during the curing period is of primary importance. Rapid loss of moisture in the hardening concrete will result in crazing (temperature cracking). This type of cracking causes rapid deterioration of the concrete, especially if the pavement is subjected to freezing and thawing cycles.

(1) *Moist coverings.* Under normal summer conditions, burlap or paper covering that is kept moist will be sufficient.

(2) *Fog spray.* Under extreme drying conditions, provision may be made to counteract the moisture loss by replacing some of the evaporated water with a fog spray The sprays may be attached to the scree carriage of the concrete finisher, or they may be hand operated. In either case, the use of sprays should be the exception rather than the rule.

c. Other Hot Weather Measures. Normal procedures such as wetting the subgrade and immediate use of curing compound after finishing become more important in hot weather. Experimental use of expedient hot weather measures should be first tried on small test areas and then expanded with close supervision over the entire project.

Section IV. REINFORCED AND PRESTRESSED CONCRETE

304. Reinforced Concrete

The use of reinforcing steel to increase flexural strength is not generally recommended for use in pavement construction. Additional load-carrying capacity may be obtained more economically by increasing the slab thickness than with reinforcing steel. Although welded wire fabric is sometimes called reinforcing mesh, it does not increase the strength of the slab.

305. Welded Wire Fabric

a. Function. The principal function of welded wire fabric (fig. 111) is to hold together fractured faces of slabs after cracks have formed. Adequate load transfer across the crack is assured by the interlocking action of the rough faces of the crack. Although infiltration of foreign materials into the crack is prevented, these cracks should be sealed with a bituminous material to prevent ice damage

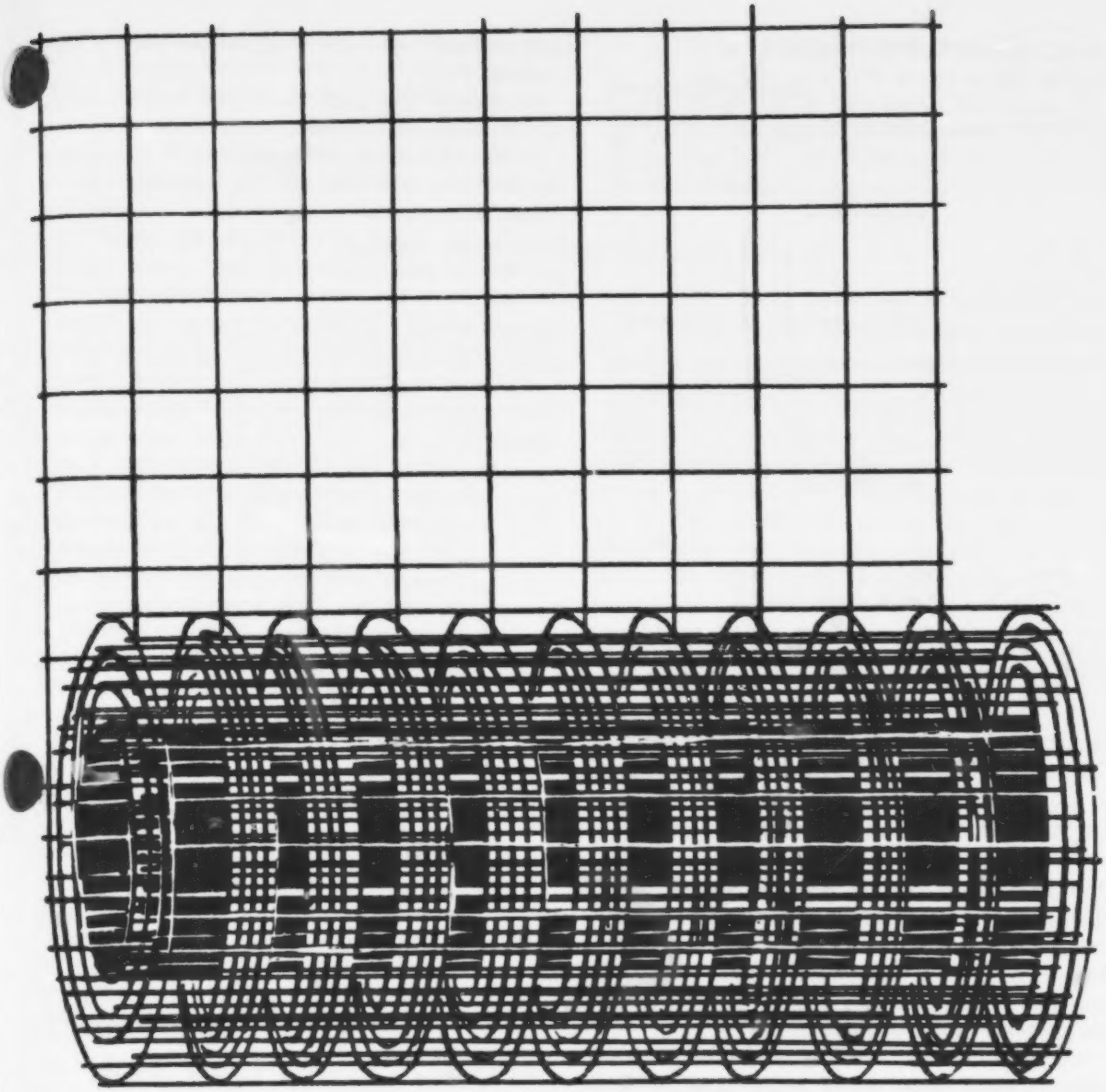


Figure 111. Welded wire fabric.

in cold weather. Unlike reinforced pavement, welded wire fabric does not increase the flexural strength of a slab when used in the quantities that are considered economical. Welded wire fabric prevents the development of intermediate cracks that may be expected in the central portion of each slab when joint spacings are excessive.

b. Placement. Welded wire fabric comes in both sheets and rolls. If rolls are used, they should be unrolled in a counterclockwise direction (fig. 112). This method of unrolling is more difficult than unrolling in a clockwise manner, but the tendency of the placed end to kick up is counteracted.

Note. After unrolling, the fabric should be inspected for irregularities and rust. All rust should be removed with wire brushes to insure a good bond with the concrete. DO NOT oil the fabric as this will also prevent bonding.

The location of the fabric within the slab is not important as long as it is not within 2 inches of any edge or the top and is more than one-half the slab thickness above the bottom. The usual procedure is to use two spreaders in the paving train.

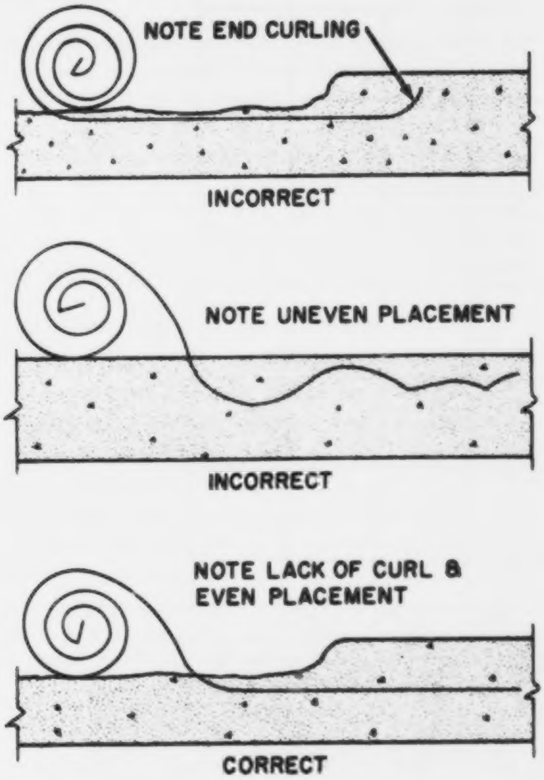


Figure 112. Method of placing welded wire fabric.

The first spreader is set to level the concrete about ½-inch above the desired level for placing the mesh. The mesh is then placed on the surface and forced into the concrete to the desired depth. Additional concrete is added and the second spreader strikes the surface off at the desired grade.

c. *Expedients.* Common steel garden fencing with the wires spaced 4 to 6 inches apart may be used as expedient welded wire fabric. This should be used as an emergency measure only, as the results are marginal. Aluminum fencing should *not* be used. Aluminum and chemicals found in some concrete mixes combine to form another compound, which has a much greater volume and causes the concrete to crack.

306. Prestressed Concrete

The use of prestressed concrete for pavement construction is a recent development that increases the strength of a slab without increasing the thickness. This greatly increases the economy of high load-capacity slabs. The actual design and construction of prestressed slabs is beyond the scope of this manual.

a. *Theory.* The principle of prestressing consists in the production of preliminary internal stresses in a structure before the working or live loads are applied in such a way that the resulting state of stress is considerably improved for withstanding the stresses caused by working loads. Initial compression is usually gained through tension applied to steel wires and rods in concrete. Because prestressed concrete is elastic, it recovers its original shape after deformation when the load is removed.

b. *Types of Prestressing.* The various types of prestressing are discussed in the following subparagraphs.

(1) *Internal and external prestressing.* A prestressed concrete structure may be stressed externally or internally. In most cases, the loading is internally applied because many problems affect external prestressing, such as shrinkage, and creep in concrete.

(2) *Linear prestressing.* Linear prestressing is used on beams and slabs. The prestressing tendons in linearly prestressed structures are not necessarily straight; they may be either bent or curved.

(3) *Pretensioning and posttensioning.* Th term pretensioning is used to describe an method of prestressing in which the tendons are tensioned before the concrete is placed. Posttensioning is a method of prestressing in which the tendon is tensioned after the concrete has hardened. Posttensioning is almost always performed against the hardened concrete and the tendons are anchored against it immediately after prestressing.

(4) *End-anchored or nonend-anchored tendons.* For posttensioning, the tendons are anchored at their ends with mechanical devices to transmit the prestress to the concrete. Such a member is termed end-anchored or mechanical end-anchored. In pretensioning, the tendons generally have their prestress transmitted to the concrete simply by their bond action near the ends.

(5) *Bonded or unbonded tendons.* Bonded tendons are bonded throughout their length to the surrounding concrete. Nonendanchored tendons are necessarily bonded tendons. End-anchored tendons may be either bonded or unbonded to the concrete. In

general, the bonding of posttensioned tendons is accomplished by subsequent grouting. When the tendons are unbonded, protection from corrosion must be provided by galvanizing, greasing, or other method.

(6) *Full or partial prestressing.* Concrete is fully prestressed when a member is designed so that there are no tensile stresses under the working load. When some tensile stresses are roduced under the working load, the concrete is partially prestressed.

Section V. MAINTENANCE AND REPAIR

307. Introduction

Prompt and adequate maintenance greatly extends the life of concrete pavements. Maintenance consists of care of joints, repair of cracks, replacement of broken areas, and correction of settlement and drainage faults. Essentially, this involves maintaining a smooth surface and keeping the subgrade as dry as possible. A smooth surface protects the pavement from the destructive effect of traffic impact and reduces wear and tear on vehicles. The procedures outlined herein should be used only as guides. Consult TM 5-624 for the step-by-step procedures.

308. Recommended Types of Cement for Repair

Standard portland cement is generally used in concrete construction, but high-early strength portland cement is preferable for repair work because repaired surfaces may be more rapidly opened to traffic. In the theater of operations, the supply of high-early strength portland cement will usually be limited; however, some of its characteristics can be obtained by using standard portland cement mixes with low water-cement ratios. In addition, up to 2 percent of calcium chloride can be used as an admixture with standard portland cement to accelerate the initial set. Such mixtures harden quickly and must be placed and finished promptly after mixing.

309. Repair of Joints and Cracks

Concrete pavements should be inspected periodically for cracks and open joints that should be cleaned, filled, and sealed to prevent seepage of water into the subgrade. This seepage causes subgrade failure and allows earth or debris to plug the joints and crack openings and prevent closing in hot weather. Repair of joints and cracks is particularly important in the fall when the pavement is slightly contracted and weather conditions are still favorable for such repair. The sealing compound used should stick to the concrete and remain plastic at all temperatures. It should not become so brittle and hard that it cracks at low temperatures, or becomes so soft that it flows from the joint even under the most intense summer heat.

a. Preparation. The joint should be cleaned thoroughly of dirt, dead sealing material, and concrete chips. Removal is more satisfactory when temperatures are below 50° F. and joints are opened by the contraction of the pavement. The existing sealer should not be removed if it is in good condition. Joint and crack faces should be dry. When a blow torch or other heating device is used to dry surfaces, care should be taken not to burn any live filler in the joint or crack. Expansion joints filled with an extruding type of filler are trimmed to the level of the surrounding pavement. The filler should not be pulled out of joints during trimming operations. Any wide cracks should be cleaned thoroughly before they are sealed. Some trimming of edges is desirable to remove overhanging sections of concrete that might break off under traffic.

b. Priming. Expansion joints should be primed before resealing with a thin mixture of 3 or 4 parts gasoline to 1 part of the asphalt selected for sealing. If tar is used, benzol should be used instead of gasoline. Flammable materials must be used with caution. Primer can be applied more successfully by brooming than by spraying, but brooming is not required if joints or cracks have been dried by application of heat.

c. Equipment. When a joint or crack is being cleaned, straight or hooked hand-operated bars are used with chisel ends shaped to fit into the joint or cracks. A sharp-edged shovel, spade, or straightened hoe may be used to cut off extruded joint filler.

(2) For complete removal of old sealing material in large quantities, a specially made hook or plow may be pulled along the joint by a tractor or with a line from a winch. The plow tooth is shaped to fit the joint and remove old material to the desired depth.

(2) Stiff fiber or wire brooms also are used to clean the joint or crack. A power sweeper will save time on extended operations.

(3) An air compressor used to blow out cracks or joints should deliver at least 100 cubic feet of air per minute at 100 pounds of pressure.

(4) For pouring small quantities of sealer, hand-pouring cones are satisfactory but larger jobs will require a distributor equipped to deliver sealing material through a joint-filling nozzle.

(5) Conventional kettles for heating bituminous materials also are suitable for asphalt or tar compounds. Kettles with provision for indirect heating are required for heating sealing compounds containing rubber or latex.

310. Repair of Spalled, Scaled, or Map-Cracked Surfaces

Areas which show extensive spalling, sealing, or map-cracking may be repaired with a bituminous patch or with cement mortar. Bituminous patches are preferred when closing the repair areas for more than 24 hours, as this would cause great inconvenience to traffic. Map-cracking is distinguished by irregular cracking over the pavement surface. Spalling is a chipping or splintering of sound pavement, and usually occurs along the joints or cracks in the pavement. Scaling usually is caused by the deterioration or disintegration of the concrete and may take place anywhere on the pavement surface.

a. Use of Bituminous Materials. When bituminous materials are used, loose and foreign material should be cleaned from the spalled, scaled, or map-cracked area. The area is then sealed with one or more applications of RC cutback asphalt, fast-setting asphalt emulsion, or light road tar, and immediately covered with coarse sand, fine gravel, or fine stonechips. When excessive spalling or scaling has occurred to a depth of 1½ to 3 inches, it may be necessary to place a base course of penetration macadam or bituminous premix. A surface treatment may then be placed over the repaired area.

b. Cement Mortar. Spalling at joints and deep surface scaling or other deep depressions can be satisfactorily patched with a cement mortar. The area to be patched is chipped to a vertical edge. All loose particles are removed and the area is cleaned thoroughly with a stiff broom or compressed air. A 25-percent solution of muriatic (hydrochloric) acid is effective in removing cement coating from surface of exposed aggregate. Thi solution must be washed away with water and the surface allowed to dry. The cement mortar is composed of 1 part cement and 2 parts sand and is thoroughly mixed. Only enough water should be added for the mortar to stick lightly together when squeezed in the hand. The surface is brushed with a thin coat of freshly mixed portland cement paste, and the depression filled and thoroughly compacted with the cement mortar mix. The surface is then stuck off and finished to match the surrounding slab.

311. Repair of Breaks

Breaks are caused by excessive expansion, unusual loads, inadequate subgrade support, washouts, and war damage. Replacement of portions of concrete pavements is necessary when broken areas have become displaced or the broken pieces are too small to distribute the load to the subgrade without settling or rocking.

a. Defective Subgrades. Defective subgrades must be improved by drainage, by removal and replacement of subgrade material, by reconstruction of subbases, or by other means as indicated by the cause. The new material is thoroughly tamped i place and the damaged portion of the subgrade brought up to the standard of the surrounding material. Poor drainage is corrected by installing subdrains or lowering the groundwater level as required.

b. Preparation of Old Concrete. Where small areas of patching are involved, rectangular patches should be used wherever possible. The upper 2 inches of the edge of the old concrete is trimmed to a vertical face to prevent thin edges in the pavement or in the patch. The remaining edge depth should be rough and free from loose fragments, dust, and dirt, to assure a good bond with the patch.

c. Concrete Patches. Concrete patches preserve uniformity. Patches can be made that are not readily distinguishable from the rest of the pavement. Patches at pavement joints and edges should be about 2 inches thicker than the original pavement, but interior patches should be the same thickness as the existing slab. The concrete mix used for patching will depend on the length of time the pavement can be closed to traffic. Normally, the pavement will be required as soon as the patch can be used. For this reason, high-early strength portland cement is desirable for patching, since it permit traffic on the patch in 24 to 72 hours. If high-early strength portland cement is not available, a low water-cement ratio, high cement factor, mixture (dry, rich mix) made with standard portland cement can be used.

(1) Before the concrete is placed, the old concrete must be thoroughly saturated with water. This increases the bond between the new patch and the old concrete. If an expansion or contraction joint intersects the patch, a joint of the same sort is constructed through the new concrete. If this is not done, a small area of the concrete will be subjected to high compressive stresses and may fail as the temperature rises.

(2) The mix is shoveled into the hole and thoroughly compacted. A surface vibrator gives best results, but satisfactory small patches can be obtained by hand-tamping. The tamp used along the edges has a small area, (a piece of 2-by 4-inch lumber is suitable), and the concrete is forced close against the slab. This is repeated again as late as possible, but before the concrete hardens so much that finishing cannot be accomplished. The patch must be cured, using methods described in paragraph 290 for new concrete pavements. The patch must be kept closed to traffic until it has developed sufficient strength to support the traffic without injury to the concrete. This period will vary from one to several days, depending upon the type of cement and concrete mixture used and the temperature of the pavement.

d. Cement-Bound Macadam Patches. Satisfactory repairs can be quickly accomplished by the use of cement-bound macadam. The hole is prepared as for a concrete patch. Crushed rock or gravel or broken concrete from the old pavement 1½ to 2½ inches in size is used to fill the hole. This material is thoroughly compacted with a vibrator or roller if available. A thick cement-sand grout, 1 part cement to 2 or 2½ parts sand, is spread over the compacted aggregate and thoroughly forced down until the voids are choked. Finishing and curing are the same as for a concrete patch. When broken concrete is used to fill the hole, large pieces are placed first by hand and laid flat sides down, and smaller pieces are used to fill the voids. The pieces of broken concrete should be firm and free from dust and dirt. In an emergency, cement-bound macadam patches can be temporarily opened to traffic before the application of the grout.

e. Bituminous Patches. Broken areas or craters in concrete can be successfully patched with bituminous materials. Penetration macadam or dense fine-graded bituminous concrete is recommended for this purpose. A thoroughly consolidated base course which gives a patch thickness comparable in load carrying capacity to the surrounding pavement is necessary. Such patches can be opened to traffic in a few hours if proper materials are used and the layers underneath the finished surface are constructed properly.

f. Emergency Patches. Emergency patches may be made by using natural soil, compacted at proper moisture content. Care must be exercised to pack the material into place from bottom to top of the patch. Such patches are suitable in winter weather or when immediate permanent repairs cannot be made. If the surface becomes sloppy under use, it can be covered lightly with fine aggregate.

312. Correction of Minor Settlements

Depressions in pavement caused by settlement of subgrade and slab can be leveled with bituminous materials, provided settling has ceased and the slab is fully supported by the subgrade. Rocking of small broken pieces of pavement under load or other movement or displacement of base course will be reflected in the bituminous patch and cause failure. Water and dirt should be brushed or cleaned from the surface with compressed air, and a thin coat of primer applied. After the primer has cured, bituminous patching material should be applied carefully to assure that the surface will be flush with the surrounding pavement after compaction.

313. Correction of Minor Settlements

The correction of major settlements in concrete pavements may require the use of special methods and equipment for filling voids beneath the pavement by bituminous subsealing or mudjacking. These methods are contained in TM 5–624.

PART FOUR

EXPEDIENT PAVING AND SURFACING OPERATIONS

CHAPTER 16

INTRODUCTION

314. Need for Expedient Pavements and Surface

Although routes of communication are of vital importance in the theater of operations, the overall need for men and equipment may greatly reduce the capability to construct these routes during combat operations. Expedient materials and methods have been developed to alleviate this problem. The engineer must choose the material and method after considering such factors as desired permanency, time available for construction, type of terrain, anticipated traffic volume and type, and future use. As long as the engineer uses sound engineering judgment, he is limited only by his ingenuity in the selection of expedient materials and methods.

315. Expedient Materials

The word *expedient* is often misleading when used in the military sense. An expedient operation is any paving or surfacing operation that must be completely quickly and whose end result is temporary in nature. Expedient materials are often divided into two groups: manufactured and natural and nonstandard.

a. Manufactured Materials. Manufactured materials are those expedient materials that are produced in a commercial factory. These include landing mats and membranes. Landing mats are rigid or semi-rigid portable surfaces that interlock to form the surface of an expedient pavement. These structures contribute to the bearing capacity of the soil, but do not necessarily protect it from infiltration (water that works its way into the soil through the surface such as the direct result of rainfall). Membranes do not contribute to the bearing capacity of the underlying soil, but they do protect the soil from loosing strength from infiltrating water. These surfaces are extremely flexible and have an additional feature of controlling dust. Under certain conditions, some of the lower forms of bituminous surfaces are also considered to be expedient surfaces.

b. Natural and Nonstandard Materials. Natural expedient materials are materials found in nature the site, such as rock, sand, timber, brush, and soil. Nonstandard expedient materials are those that are produced for some purpose other than road construction. These include precut lumber, tarpaper, sandbags, and bricks. Natural and nonstandard materials may be used to construct both pavements and surfaces.

316. Special Considerations

a. Drainage. Drainage in expedient operations is as important as for standard paving operations. Since most expedient structures are of a short design life, seasonal considerations must be made in the examination of the need for drainage. Other considerations may outweigh the risk taken in underdesign of drainage structures. The main factors that should be considered are:

(1) Probability of precipitation and its intensity.

(2) Storm duration and use of alternate routes should the planned road be blocked.

(3) Ratio of time, men, and materials used in the original construction of adequate drainage facilities to those needed to repair an

maintain the inadequately designed road or airfield and the loss of that structure during the storms and subsequent repairs.

(4) Delays during construction.

b. Soil Stabilization. Soil stabilization is discussed in TM 5-335 and TM 5-530. Soil stabilized mixtures may be used as a wearing surface if the surface is to withstand very light traffic. Soil stabilization usually is used to improve the existing subgrade soil. It increases the bearing capacity of the soil sufficiently so that the thickness of the base course may be reduced or the need for a base course may be eliminated entirely. Stabilization can also assist in dust palliation and soils waterproofing.

c. Future Use. The future use of the structure should also be taken into consideration. Present conditions may dictate the use of expedient materials to construct a road for which future improvements are planned. The expedient materials should be compatible with those contemplated for use in the future to avoid unnecessary delays in removal of the old material.

CHAPTER 17

MATS

Section I. INTRODUCTION

317. Types

The pierced plank types of mats are the only types currently available through the Army supply system. (These pierced planks should not be confused with the World War II PSP and PAP, which are obsolete.) The M6, M8, and M9 mats are limited standard as they do not meet present mat criteria. Several new types of mats are now in the advanced testing stages. Three of the new mats are discussed in paragraphs 340 through 342, as present engineering tests indicate that construction procedures will probably not be affected by any future modifications.

318. Designation

New criteria have been set forth to aid in the designation of various types of mats. Two general categories, light mats and heavy mats, have been established.

a. Heavy Mats. Heavy mats must be able to withstand 200 simulated coverages of a 25,000-pound single wheel load with a tire pressure of 250 psi on a subgrade with a CBR value of 4. These criteria must be met without the occurrence of excessive deflection under load and no more than 10 percent replacement of failed panels. Other requirements are that these mats must weigh less than 5.0 pounds per square foot of usable area and be in sections small enough to be readily erected by hand.

b. Light Mats. Light mats must meet the same criteria as heavy mats except that the CBR value of the subgrade is raised to 10 and the maximum weight is restricted to 3.0 pounds per square foot of usable area.

Note. The major difference between light and heavy mats is the CBR requirement for the base and the weight per square foot. This allows units in the field to construct an airfield (or road) from the lightest possible mat upon evaluating soil conditions, thus saving valuable transport capacity for other items.

319. Design and Evaluation

Design criteria for the use of landing mats are usually expressed in the form of pavement (or base course) thickness reductions as related to wheel load, tire pressure, subgrade strength, and usage level. Standard design curves for evaluating the capacities of M6, M8, and M9 mats are in TM 5-330. Similar curves will be made available for the evaluation of the prototype mats, MX18B, MX18C, and MX19, as these items become standardized.

Section II. M8 AND M9 MAT

320. Description

a. M8 Mat. The M8 mat (fig. 113) is an improved version of World War II pierced mats. This widely used item is the best available mat currently in the Army supply system. It is manufactured from rolled steel plate with four rows of punched holes that reduce the weight to 140 pounds per standard panel. The nominal size of a standard panel is 11 feet 9¾ inches (11.8 feet) by 19.5 inches, resulting in a unit weight of 7.3 pounds per square foot of usable area. Between the four rows of holes are three longitudinal ridges which increase the longitudinal rigidity. The panel has T-shaped, inverted bayonet connectors on one side and slots on the other. Interior locking lugs behind the bayonet connectors fit into recesses in the slots, preventing longitudinal slippage. The M8 will support a 50,000-pound single wheel load and an 80,000-pound dual wheel load on a CBR 15 subgrade for 700 coverages. The M8 is packaged in bundles containing 13 standard and 2 half panels

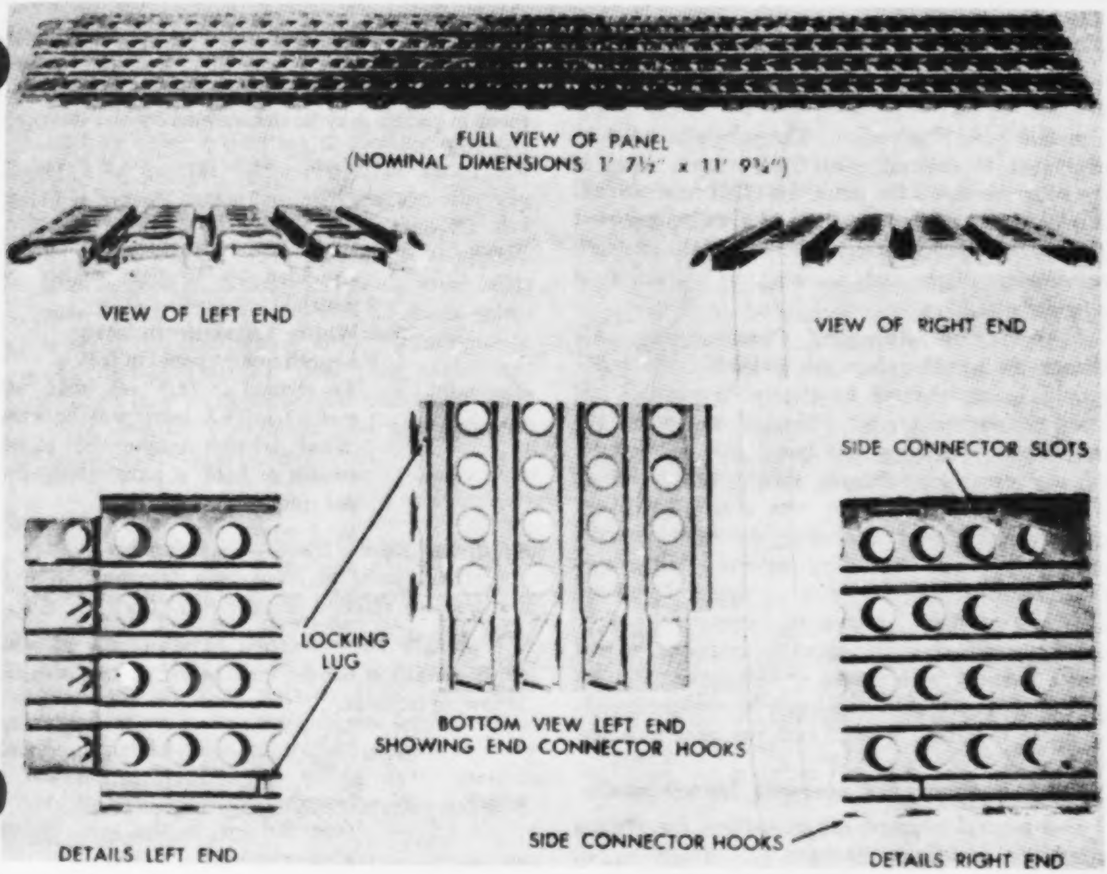

FULL VIEW OF PANEL
(NOMINAL DIMENSIONS 1' 7½" x 11' 9¾")
VIEW OF LEFT END
VIEW OF RIGHT END
SIDE CONNECTOR SLOTS
LOCKING LUG
BOTTOM VIEW LEFT END SHOWING END CONNECTOR HOOKS
SIDE CONNECTOR HOOKS
DETAILS LEFT END
DETAILS RIGHT END

Figure 113. M8 Mat.

b. M9 Mat. The M9 mat is identical to the M8 in appearance except that it is made from aluminum and the panel width is increased to 22¼ (22.2) inches. The panel weight is decreased to 67 pounds and the unit weight is 3.1 pounds per square foot of usable area. The packaging method and load bearing capacity of the M8 and M9 are identical except that the design life of the M9 is only half that of the M8 mat. These two mats are interchangeable as long as only one type is used per row. The difference in widths precludes their use in the same row.

321. Advantages and Disadvantages of M8 and M9 Mats

a. Advantages.

(1) Both have a low cubage to surface area ratio.

(2) M9 has a relatively low weight to surface area ratio.

(3) Both are reusable although this becomes proportionately more difficult with use.

(4) Both are excellently suited for road surfacing.

(5) Special skills are not required.

(6) Maintenance is simple due to relative ease in replacing panels and ability to roll up mat to repair subgrade.

b. Disadvantages.

(1) M8 has a high weight to surface area ratio.

(2) M9 end connectors are easily broken off.

(3) Definite placing patterns are necessary.

(4) Holes cause problems due to pumping, dust, and softening of subgrade during rain.

(5) Both are slippery when wet.

322. Foundations

A detailed discussion of subgrade and base course preparation is given in TM 5–330.

a. Subgrade Evaluation. The subgrade must be evaluated to determine its CBR value. Even if the subgrade meets the minimum CBR requirement, it may be more economical to add a well-compacted (high CBR) base course. This reduces the strength requirement of the mat, allowing the utilization of a lighter mat.

b. Grade and Alinement Considerations. Although no actual values are available, the grade should be maintained as closely as possible. If small depressions are not filled and compacted, the maximum capacity of the panel will be reduced. In any case the subgrade should be leveled to practical limits and rolled with sheepsfoot, pneumatic-tire, or steel-wheel rollers. Alinement is critical with mats as correcting for errors will sometimes result in difficulty in connecting the next run (or row) of mats. Alinement corrections can be made to some extent by actually dragging the mat into alinement with trucks or bulldozers. No appreciable alinement changes can be realized by attempting to stretch or bend each run back into line.

323. Sequence of Placement Operations

The general sequence of operations for placing all types of mats is as follows:

a. Determining the material and manpower requirements.

b. Organizing the job and specific tasks.

c. Establishing original alinement.

d. Spotting bundles.

e. Spotting, carrying, and placing panels.

f. Locking joints, if necessary.

g. Checking alinement.

h. Stretching plank, if necessary.

i. Finishing sides and ends, if necessary.

j. Forming junctures, if necessary.

k. Anchoring, if necessary.

l. Laying hardstands and fillets (airfields).

The placement procedures outlined in paragraphs 324 through 336 are specifically written for M8 and M9 mats. Deviation from these procedures will be necessary when using other types of mats or when unusual conditions dictate changes.

324. Material Requirements

Material requirements are most easily determined in four steps: width determination, length determination, total panels, and additional material deter-minations.

a. Width Determination. The width of the pave-ment in panels may be determined by the following formula:

$$N_w = \frac{W_s}{L_p} \qquad (17\text{–}1)$$

where, N_w = Width of structure in panels (rounded *up* to next higher 0.5 panels)

W_s = Width of structure in feet

L_p = Length of mat panel in feet

Example: An airfield is 72.0 feet wide. M8 mat ($L_p = 11.8$ feet) will be used. What is the number of panels (width of field in panels) required per run?

Solution: $N_w = \frac{W_s}{L_p} = \frac{72.0}{11.8} =$ *6.1 panels*

Rounding up, 6 standard panels and 1 half panel would be used per run.

b. Length Determination. The number of runs, or the length in panels, may be calculated with the following formula:

$$N_L = \frac{12 \times L_s}{W_p} \qquad (17\text{–}2)$$

where, N_L = Length of structure in pane (rounded up to the next highest whole number)

L_s = Length of structure in feet

W_p = Width of panel in inches

Example:

The airfield in paragraph 324*a*, above, is 3,000 feet long. The width of the M8 mat panel is 19.5 inches. How many runs of mat are required?

Solution:

$$N_L = \frac{12 \times L_s}{W_p} = \frac{12 \times 3000}{19.5} = 1846.2 \text{ or } \mathit{1847\ runs}$$

c. Total Panels. The total number of panels is determined by estimate. The governing factor is the number of panels in the runway, taxi strips, and hardstands. This figure is obtained by successive use of the following formula:

$$N_T = N_w \times N_L \qquad (17\text{–}3)$$

where, N_T = Total number of panels for structure

N_w = Width of structure in panels (panels per run)

N_L = Length of structure in panels (number of runs)

After calculating the total number of panels for each structure, the totals are added together. Additional panels are necessary for such items as fillets in turns. These additional requirements may be obtained by either estimation or plotting on graph paper. Also, another factor should be added that considers waste, anchorage, and bent or otherwise unusable panels. Factors of 5 percent for new planks and 10 percent for recovered planks appearing to be in good condition will usually yield fairly accurate results. Figure 114 shows a sample calculation sheet for determining airfield requirements.

d. Additional Materials. Steel pins, cables, and extra panels may be necessary for anchorage. Dust palliative, erection equipment, and manpower requirements should also be considered.

325. Job Organization

a. Two typical organizations for laying M8 and M9 landing mat are shown in table XVIII and figure 115. For table XVIII, a platoon is the basic unit and the tactical integrity is maintained by squad assignments to carrying and placing, with the other squad taking all other details. If the supervisor takes this or some such proportional breakdown of his unit, and he fully knows and understands the operations involved in the laying of the mat, he can adjust his organization as bottlenecks and additional requirements arise.

b. Depending upon the size of the job and the number of men available, there are several ways the job can be organized. With only one laying crew, normally laying would start at one end of the runway and proceed to the other end.

c. If personnel are available, two crews may start at the transverse centerline and lay mat toward both ends of the runway simultaneously. As M8 and M9 panels have connector slots on one side only and connector hooks on the other, it is necessary to weld a joint at the transverse centerline so that planks can be laid in each direction. The welded transition panels will have connector slots on both sides to receive the connector hooks of panels being placed in either direction. This permits panels to overlap previously placed panels in the normal placing pattern (fig. 116). A third crew about as large as a platoon may be used in anchoring the mat along the edges of the runway and in stretching and alining the mat. After alining the mat at the center, the time required to lay the runway can be cut almost in half by using two crews. Also the runway can be laid from both ends and welded at the center after cutting. This usually requires more time than the first-mentioned method, and it does not provide for partial occupancy before the field is completed as the one-mat method does. See paragraph 335 for special considerations that should be made when planning junctures.

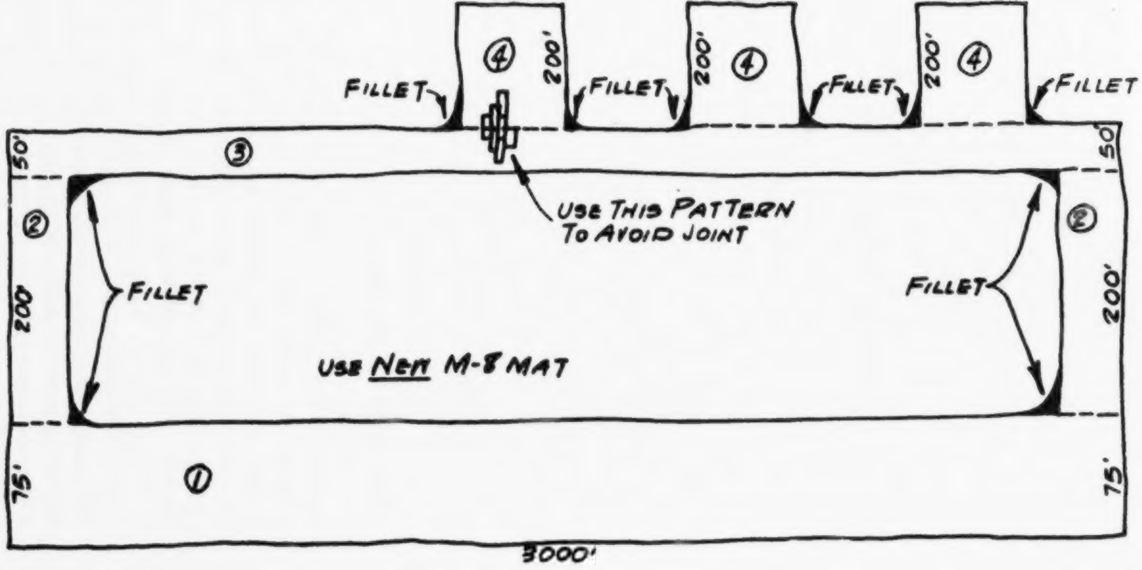
d. With four laying crews working simultaneously, the time required for laying an M8 or M9 runway can be approximately quartered. In this case, two crews begin at the transverse centerline of the runway, and one crew each begins at the two ends and works toward the quarter points. A juncture problem will occur at the quarter points of the runway, since the panels cannot be interlocked. Panels at the juncture point must be cut and welded together to make the transition joint as smooth as possible (fig. 116).

e. Another variation of the four-crew method mentioned in *c* above, is to start two crews each at the two quarter points with their initial runs welded together. The whole runway should then be welded together when the two center crews meet at, or near, the center (fig. 116).

f. If only the touchdown areas are to be surfaced with landing mat, one crew can surface one and then the other, or two crews can work simultaneously, one in each touchdown area. The touchdown area can be placed either from the runway ends toward the inside edge of the touchdown area, or from the inside edge of the touchdown area toward the end of the runway.

326. Spotting Bundles

a. Method. Where feasible, the haul of landing mat to the site should not begin until grading operations on the runway have reached a point that will permit unloading of bundles without rehandling. To speed the handling of the M8 or M9 bundles, special slings or tongs may be improvised. A truck-mounted A-frame or some type of mobile crane or lifting device is most satisfactory for unloading bundles. Although, in an emergency, bundles may be dumped from dump trucks, the bending, twisting, and warping of the individual panels in the process will lead to later difficulty. Direction is established by the fact that the mat placers face the completed runway as they work. Therefore, the completed runway is the front of the job, and the bare subgrade, or base, behind them is the rear. The hauling vehicle, with its unloading device and spotters, spots the bundles to the rear of the job, minimizing


150'
150'
150'
④
④
④
200'
200'
200'
FILLET
FILLET
FILLET
FILLET
③
50'
50'
②
②
200'
200'
FILLET
FILLET
USE THIS PATTERN TO AVOID JOINT
USE NEW M-8 MAT
①
75'
75'
3000'

①

$N_W = \frac{75}{11.8} = 6.4 \cong 6.5$

$N_L = \frac{12 \times 3000}{19.5} = 1{,}850$

$N_T = 6.5 \times 1{,}850$

$= \underline{12{,}025\ \text{PANELS}}$

②

2 STRIPS

$N_W = \frac{50}{11.8} = 4.2 \cong 4.5$

$N_L = \frac{12 \times 200}{19.5} = 123$

$N_T = 2 \times 4.5 \times 123$

$= \underline{1107\ \text{PANELS}}$

③

$N_W = \frac{50}{11.8} = 4.2 \cong 4.5$

$N_L = \frac{12 \times 3000}{19.5} = 1{,}850$

$N_T = 4.5 \times 1{,}850$

$= \underline{8{,}325\ \text{PANELS}}$

④

3 STRIPS

$N_W = \frac{200}{11.8} = 17.0$

$N_L = \frac{12 \times 150}{19.5} = 93$

$N_T = 3 \times 17 \times 93$

$= \underline{4{,}743\ \text{PANELS}}$

FILLETS

ESTIMATE
120 PANELS
PER FILLET

10 x 120 = 1,200 PANELS

TOTAL

12,025
1,107
3,325
4,743
1,200
27,400

GRAND TOTAL
(ASSUME 5% LOSS & DAMAGE FACTOR)
27,400 x 1.05 = 28,770 PANELS

Figure 114. Sample calculation sheet for number of mat panels required for an airfield.

Personnel	Unit	Laying crews						Legend		
		50 runway			125 runway					
		OFF	NCO	EM	OFF	NCO	EM	OFF	NCO	EM
Supervisor	Plt Hq	1	1		1	1		●	○	
Plank placers	Squad		1	10		1	12		⊕	⊕
Plank carriers	Squad		1	10		1	12		⊝	⊝
Other details	Squad		1			1			-○-	
Locking ends				3			3			⊙
Bundle spotters				2			2			⊖
Bundle openers				4			6			-○-
Truck driver				1			1			⦶
Total	Platoon	1	4	30	1	4	36			

Table XVIII. Typical Organization for Mat Laying Crew

the carrying distance as much as possible, yet leaving sufficient working room. These vehicles travel on the subgrade, or base, rather than on the finished mat to prevent seating of the mat prior to checking the alinement. The bundles may be spotted on the shoulders along both sides of the runway, or they may be spotted out across the subgrade, or base, sufficiently behind the laying crew to produce working room. In either case, their spacing may be computed for best organization and maximum results with minimum effort.

b. Example. For an M8 mat runway, 53.2 feet wide (fig. 115), two bundles cover six runs or 9.8 feet, with one panel cut into half and one panel left over. One bundle every 9.8 feet along the centerline spaced in the center of each half of the runway will make a good working arrangement. The first two bundles should be placed 10 to 15 feet from the forward edge of the mat to provide working room and minimum carrying distance. Likewise, the bundles may be spotted on the same spacing on both shoulders of the area, starting approximately 5 feet from the forward edge of the mat using the above spacing for bundle spotting. A further possibility is to space three bundles across the subgrade, their longitudinal spacing to be 14.6 feet with initial piles 15 to 20 feet behind the forward edge of the mat. An M9 mat, 130 feet wide, as shown in figure 115, may be planned in the same manner but with more possibilities. Twenty-one whole panels are needed every two runs, or at 3.7-foot intervals, with surplus half panels. A bundle of 13 whole panels will be needed approximately every 2 feet with an initial setback from end of runway of approximately 3 feet for working room. Also, the bundles can be spotted in the middle of each half of the runway at the same 4.5-foot spacing with the initial work area 5 to 7 feet deep. Two, three, or four bundles each can be spotted on each shoulder or in the center of each half of the runway every 9 feet, 13.5 feet, and 18 feet, respectively. One bundle can be spotted behind each of the six teams every 13.5 feet, with initial working area of 14 to 16 feet. These are only a few of the many possibilities.

327. Spotting and Carrying Plank

When bundles have been spotted, the bundle openers clip all wires and steel bands to ready the planks for the plank carriers. Plank carriers work in pairs, and their primary duty is to maintain a sufficient quantity of the right panels in the hands of the placers to keep the job progressing. The carriers may be broken down in pairs so that there may be equal distribution of personnel to each pile of bundles; so that each pair will support always the same pair of placers; or so that under the supervision of the squad leader, a continuous flow

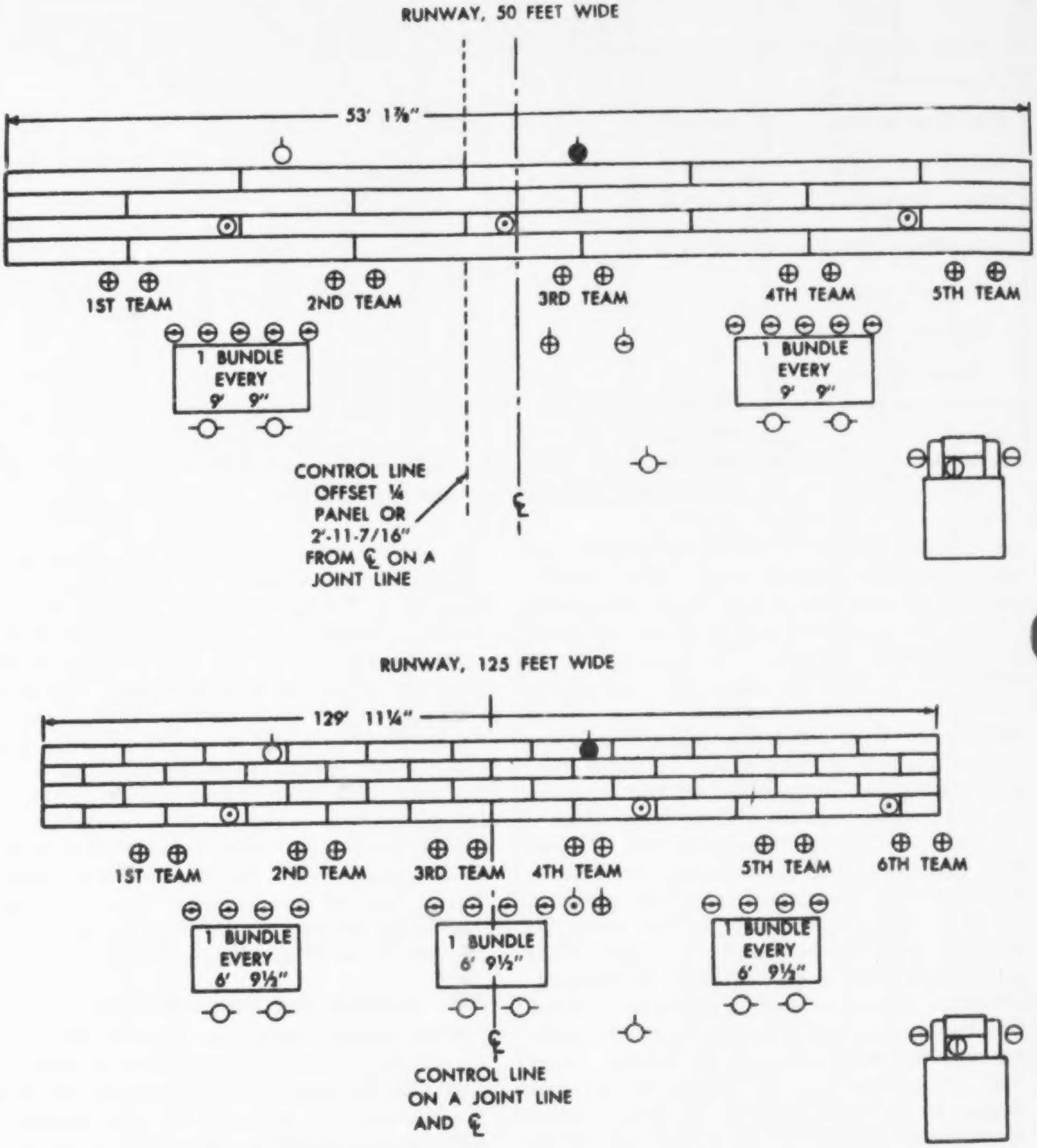

RUNWAY, 50 FEET WIDE
53′ 1⅞″
1ST TEAM
2ND TEAM
3RD TEAM
4TH TEAM
5TH TEAM
1 BUNDLE EVERY 9′ 9″
1 BUNDLE EVERY 9′ 9″
CONTROL LINE OFFSET ¼ PANEL OR 2′-11-7/16″ FROM ℄ ON A JOINT LINE
℄
RUNWAY, 125 FEET WIDE
129′ 11¼″
1ST TEAM
2ND TEAM
3RD TEAM
4TH TEAM
5TH TEAM
6TH TEAM
1 BUNDLE EVERY 6′ 9½″
1 BUNDLE 6′ 9½″
1 BUNDLE EVERY 6′ 9½″
℄
CONTROL LINE ON A JOINT LINE AND ℄

Figure 115. Job organization for laying M8 and M9 mat.

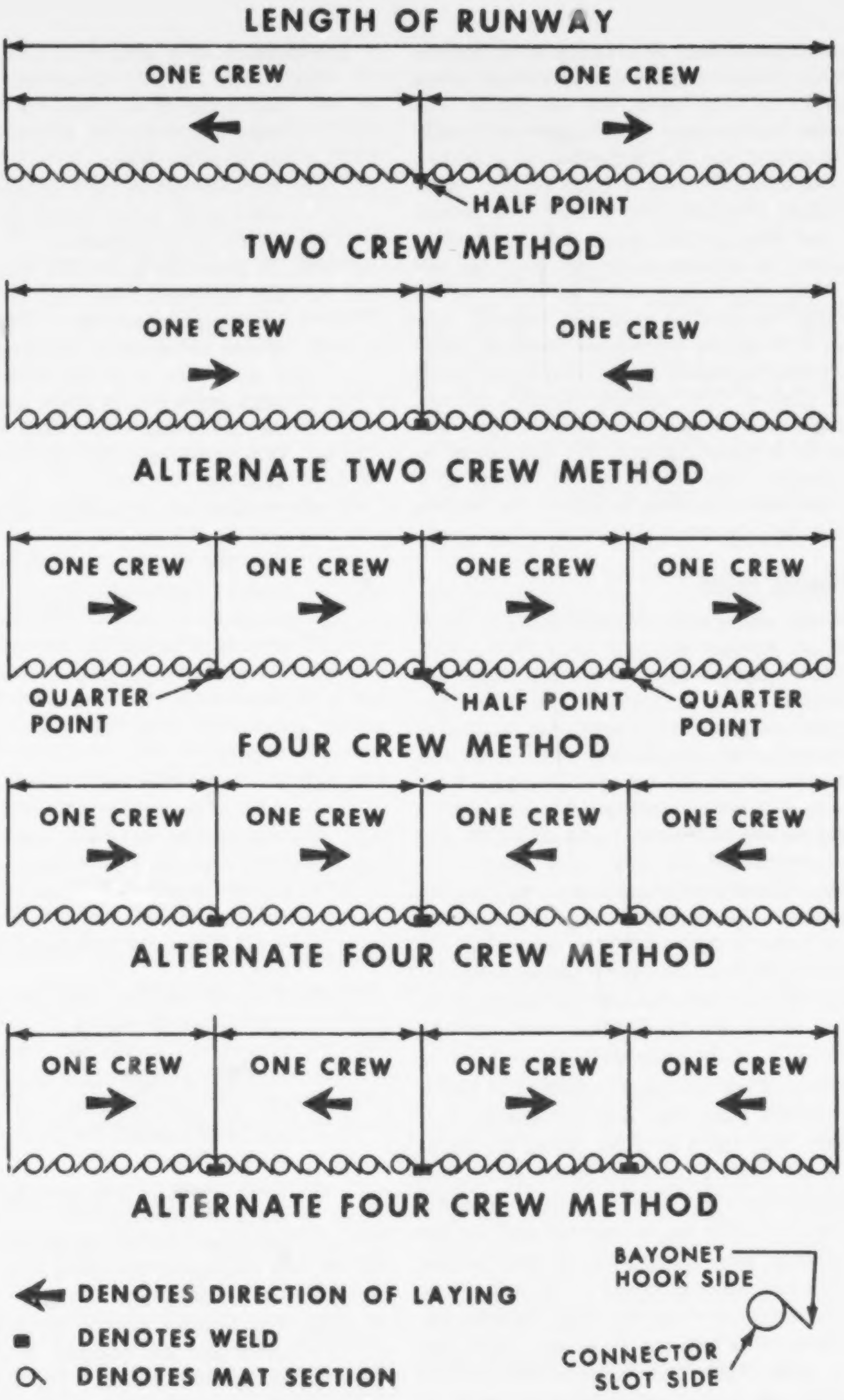

LENGTH OF RUNWAY
ONE CREW
ONE CREW
HALF POINT
TWO CREW METHOD
ONE CREW
ONE CREW
ALTERNATE TWO CREW METHOD
ONE CREW
ONE CREW
ONE CREW
ONE CREW
QUARTER POINT
HALF POINT
QUARTER POINT
FOUR CREW METHOD
ONE CREW
ONE CREW
ONE CREW
ONE CREW
ALTERNATE FOUR CREW METHOD
ONE CREW
ONE CREW
ONE CREW
ONE CREW
ALTERNATE FOUR CREW METHOD
DENOTES DIRECTION OF LAYING
DENOTES WELD
DENOTES MAT SECTION
BAYONET HOOK SIDE
CONNECTOR SLOT SIDE

Figure 116. Procedure for laying M8 and M9 mats with multiple crews.

of the correct panels may be available to the placers. When three or more bundles are distributed across the subgrade, or base course, the half panels from any interior bundles must be carried to the outside edge of the field, and equal distribution should be made to both sides unless a large surplus exists. Whole panels should be cut in half at a central location and then the half panels distributed along the shoulders to supplement the manufactured half panels. If the organization is set up to include too many plank carriers, all personnel assigned may not be used; if too few carriers are assigned, placement may stop because of lack of material in hands of plank placers. The spotters, bundle openers, and carriers must be constantly alert to spot and reject panels so badly damaged that they cannot be readily placed. Two panels can be carried at a time by one pair of carriers as long as the carriers do not lose time in carrying the panels to the placers.

328. Placing Plank

a. Locking and Plank Orientation. The panel has both an overlap end and an underlap end. Because the longitudinal overlap of panels is approximately 2 inches, the underlap end, which has the recessed end with L-shaped end connector hooks, must be on the bottom. (The underlap end is the left end of the top panel in figure 113.) The overlap end, which continues the cross section of a major portion of the panel without a hole over the last 5 inches and has slots in the sides of the rib for the end connector hooks to engage, is then placed on top. (The overlap end is the right end of the top panel in figure 113.) A reversal of the underlap and overlap positions is not possible because the underlap end ribs will not seat fully to the bottom of the overlap ribs and, if forced into place, the recessed underlap end will prohibit an even surface. When the general method of laying the M8 and M9 panels has been established, it is readily seen that the first panel placed should be the one in the forward left-hand corner of the field (as the laying crew faces its work) with the bayonet lugs facing away from the laying crew and the slot side adjacent to them. This places the underlap end on the right and the overlap end on the left. Next, this run is completed across the strip, with the following runs starting from the left as soon as one and a half or more panels are placed in the previous run, building the mat opposite the direction faced by the laying crew as the work progresses.

b. Procedure for Laying With One Laying Crew.

(1) Placers start by laying one run of planks across the runway from the left side to the right side, being sure the centerline will fall at the proper place.

(2) A transit can be used on this and the next few runs to insure planks are laid perpendicular to the centerline.

(3) As shown in figure 115, pairs of placers are numbered from left to right. Plank placing team number 1 places one or two planks as required and directed; number 2 places one or more planks, etc. If the situation warrants, each team may place only one plank each. Each pair of placers thus places one, two, or more planks in each run.

(4) The first run is made by laying plank one; overlapping the overlap end of plank two over the underlap end of plank one by 2 inches; overlapping the overlap end of plank three over the underlap end of plank two by 2 inches, etc. Overlapping is accomplished by lining up the slots in the sides of the ribs so that the L-shaped end connector hook will secure both planks together.

(5) For the second and succeeding runs, the order of placement from left to right continues; however, half panels are used to start alternate runs to assure staggering of joints. Also, team number 1 will start placing the third run as soon as team number 2 places its first panel in the second run.

(6) Then, in turn, as in the first run, construction proceeds from left to right consecutively. This means the runway will always look like a set of stairs with placement on the left far exceeding that on the right, and team number 1 will finish work before the last team.

(7) Each team of two men holds the loose plank at approximately a 45° angle to the laid plank just as though they were going to fold it over to make a sandwich with the two top sides in the middle.

(8) The bayonet lugs of the loose plank are down and are engaged in the side slots of the laid planks. The tilted plank is thus slid until the bayonet lugs are securely locked in the slots and the locking lug

behind the bayonet lugs is positioned in the slots. The locking lugs behind the bayonet lugs will fit into one of the two locking lug slots of the laid plank to prevent future sliding when the loose plank is lowered back to the ground in its final position.

(9) To make the connections lock, all panels in a run must be slid in the same direction, either left or right. Panels in alternate runs are slid in the opposite direction to maintain edge alinement and to ease removal for maintenance.

(10) The method of fastening end connectors is illustrated in figure 117. All connectors should be properly engaged with a pinch-bar. If any of the connectors are bent out of place, they may be straightened with a sledge or claw hammer so that they can be engaged in their proper slots.

329. Locking Ends

The plank placers automatically lock the sides of the planks together when they insert the connector hooks, slide the panel to aline the locking lugs and slots, and drop the new panel into position. The end-connector man then moves the end connectors into the connector slots using a pinch bar as illustrated in figure 117.

Caution: The end of the panels must be connected as they are laid because the end connectors will not fit into the connector slots if the planks are allowed to creep apart.

330. Adjustment for Temperature Change

To offset temperature changes as much as possible, a landing mat laid in any weather should be occasionally stretched from both sides and the ends by attaching vehicles and/or tractors and pulling. In general, the fit is with so little tolerance that there is insufficient protection against radical temperature changes.

331. Maintaining Alinement

a. The survey party should be available to keep a constant check on alinement. This may be accomplished with a transit or by using the 3-4-5 triangle method. Drift or misalinement must be corrected at the time the mat is being stretched. The use of temporary anchor stakes at the runway edge as the planking is laid assists in maintaining alinement.

b. When a runway has an even number of planks per run, alinement may be controlled by placing a line along the centerline (fig. 115). This line is then used to control the alinement by assuring that the joint falls along it. The control line is one-half panel off centerline for runs of odd panels, and one-quarter off centerline for runs with single half panels.

332. Stretching

After every 60 to 70 feet of runway has been placed, laying operations are suspended, and the section is stretched tightly by using truck winches or any other equipment available. Rebound can be prevented by driving temporary pickets or stakes through holes in the planks after each stretching operation. This stretching is necessary to maintain alinement and prevent buckling of panels.

333. Finishing Sides of Runway

To prevent curling and shifting, the planks must be anchored along the sides of the taxiway or runway. This may be done in several ways.

a. In the most common method, the extending portions of panels are bent downward into a trench and the trench is backfilled (fig. 118). Where half planks are being used to finish the sides of the runway to an even line, using a full plank at the end of every fourth or sixth run and burying the extension is most satisfactory and involves less waste of plank and effort. The extended section is bent by a roller or truck. A cutting torch may be used to cut out a small notch in the ribs, thus greatly reducing the load required to bend the plank and controlling the point of bending.

b. Where the whole edge, for 1- to 2-foot width, is to be bent down into a ditch, a heavy roller or wheeled vehicle may be used if care is taken, as shown in figure 119 where hardpan limited the depth of the ditch only.

c. If the ditch is not too deep, often a large pipe or cylinder can be rolled under the edge of the lifted landing mat, and the mat can be bent or beaten with a sledge hammer into a bend.

d. If finished to an even edge, the mat is anchored with cables or racked wire to deadmen buried at the side. Also, anchors can be driven into some of the outside holes of pierced plank, if the soil will firmly hold them.

334. Finishing Ends of Runway

A trench is excavated at each end of the runway across the entire surfaced width. The plank is con-

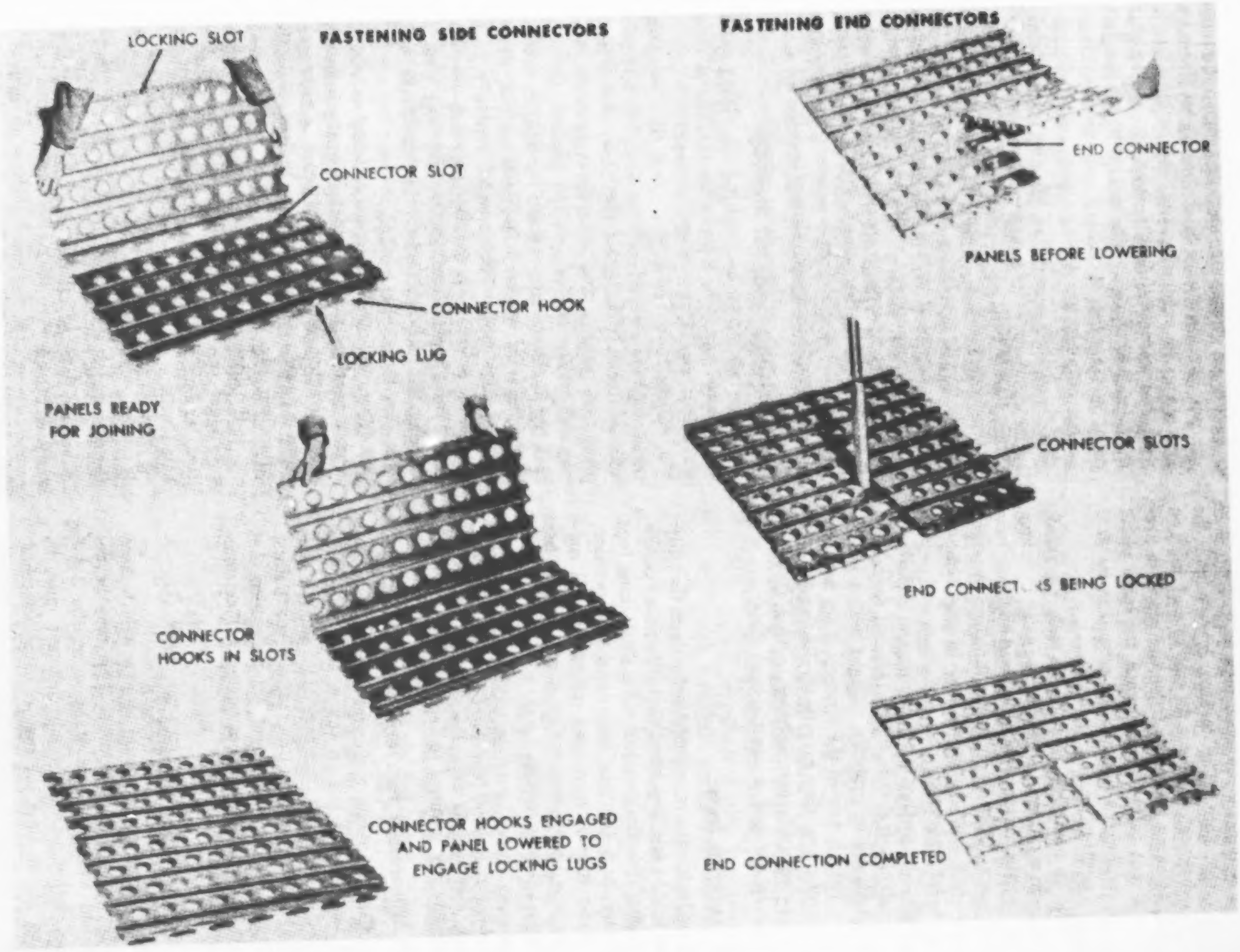

FASTENING SIDE CONNECTORS
FASTENING END CONNECTORS
LOCKING SLOT
CONNECTOR SLOT
CONNECTOR HOOK
LOCKING LUG
PANELS READY FOR JOINING
END CONNECTOR
PANELS BEFORE LOWERING
CONNECTOR SLOTS
CONNECTOR HOOKS IN SLOTS
END CONNECT…S BEING LOCKED
CONNECTOR HOOKS ENGAGED AND PANEL LOWERED TO ENGAGE LOCKING LUGS
END CONNECTION COMPLETED

Figure 117. Method of fastening M8 and M9 mat side and end connectors.

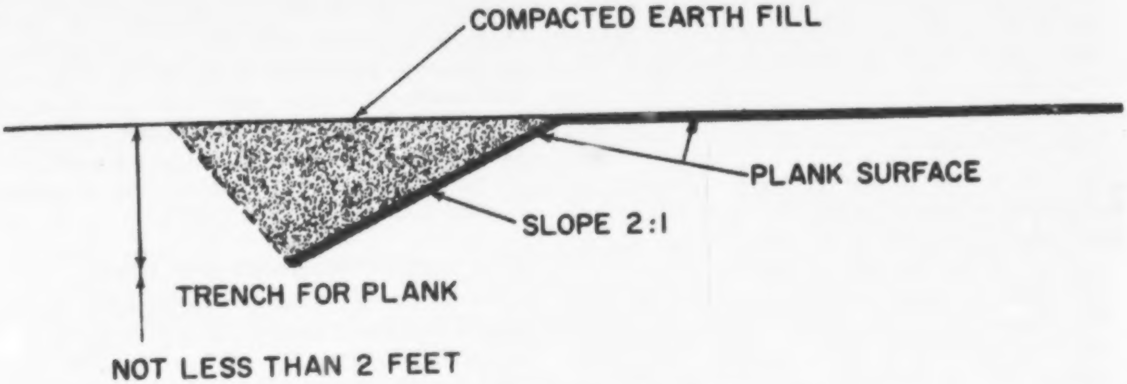

COMPACTED EARTH FILL
PLANK SURFACE
SLOPE 2:1
TRENCH FOR PLANK
NOT LESS THAN 2 FEET

Figure 118. Trench anchorage for mat at edge of runway.

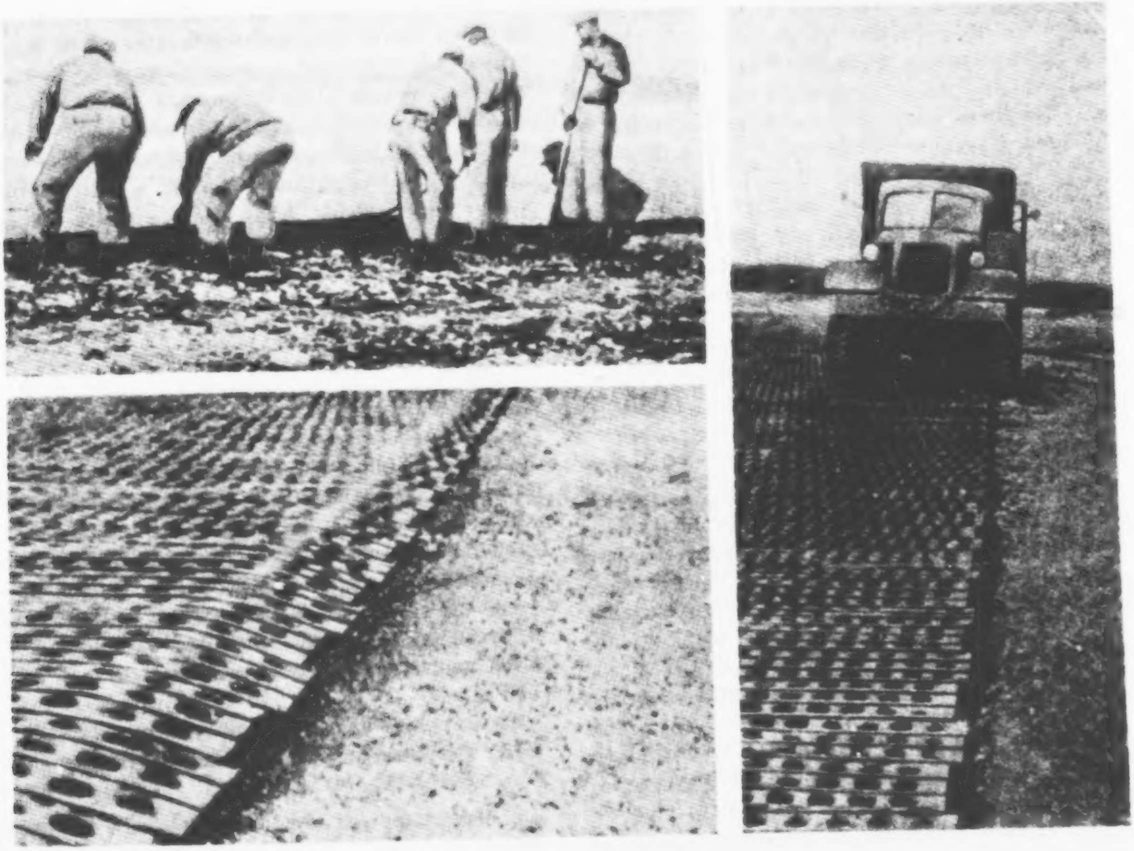


Figure 119. Method of anchoring plank placed on hardpan subgrade.

tinued down the slope of the trench about the width of six panels as shown in figure 118. After the plank is in place and anchored, the trench is backfilled and the fill compacted. This method of end finishing tends to reduce shifting and curling at runway ends.

335. Junctures

a. Use of M8 or M9. M9 may be welded if aluminum welding equipment is available; but it is advisable to use M8, if available, for the run on each side of the juncture so that the juncture can be formed by welding the steel planks together. When crews laying plank from opposite directions meet, the juncture must be welded. The welded juncture may be formed by cutting the planks with a torch and making a butt weld. It is more satisfactory to cut both planks to be welded in a rib valley, if possible. The joint can be strengthened by welding short pieces of strap iron at intervals over the joint. The method used with M6 of flattening the bayonet hooks, overlapping the planks, and welding the lap is not satisfactory for an M8 or M9 runway joint. The deep ribs of the M8 or M9 give an appreciable bump to such a joint.

b. Formation of Angles. The M8 method of forming angles is the recommended method where using M9 welding presents a problem. The skew panels are cut so that they butt up snugly against the straight panels, and then they are butt welded or spot welded. The cutting edge may be most easily determined by lifting up the last run of straight panels, and upon overlapping it on top of the skewed panels, its edge will act as a straightedge for marking. In the special case where plank taxiway, hardstand, or other similar surfaced areas join a concrete or asphalt surface, the last two planks are buried in the manner explained in paragraph 334 for runway ends, except that concrete or asphalt mixture is used to bury the joint.

336. Laying Hardstands and Fillets

Hardstands may be constructed by extending the landing mat in the taxiway; or a juncture may be formed by welding, and the planks placed perpendicular to the line of travel of the aircraft. In both methods, each run of plank is stopped after crossing the design edge of the fillet or hardstand so that a fillet is formed, but the edge is left stepped. The first method places the plank parallel to the line of travel, but it is satisfactory because of the small volume of travel, but it is satisfactory because of the small volume of travel on a hardstand. It has the advantages of ease of construction and of saving time and material. Staking down the edges of either type of hardstand generally is satisfactory. Where time permits, edges of hardstands can be buried. The forward edge of the hardstand should be buried in the same manner as the runway ends to prevent curling.

Section III. M6 MAT

337. Description

The M6 mat (fig. 120) is an improved version of the World War II PSP. Although this mat is no longer manufactured, a large quantity has been stockpiled and may be available. It is manufactured from rolled steel plate with three rows of punched holes that reduce the panel weight to 68 pounds for the standard panel. The nominal size of the standard panel is 10 feet by 15 inches, thus the unit weight is 5.4 pounds per square foot of usable area. Between the three rows of holes are two longitudinal valley ridges which increase the bridging capacity by increasing the longitudinal rigidity (This actually increases the transverse rigidity of the connected structure.) The panel has bayonet-type connecting devices (L-shaped and pointed in only one direction) and slots along both longitudinal edges enabling the unit to be placed and joined from either side. There are 29 side connector slots along each edge of the standard panel and 14 on each side of the half panel. The M6 will support a single wheel load of 37,000 pounds on a subgrade CBR of 15 for 700 coverages. The M6 mat is packaged in bundles containing six subbundles. Each subbundle contains four standard and two half panels.

338. Advantages and Disadvantages of M6 Mat

a. Advantages. The advantages of the M6 mat are—

(1) Low cubage to surface area ratio.

(2) Relatively low skill level of personnel used to place mat.

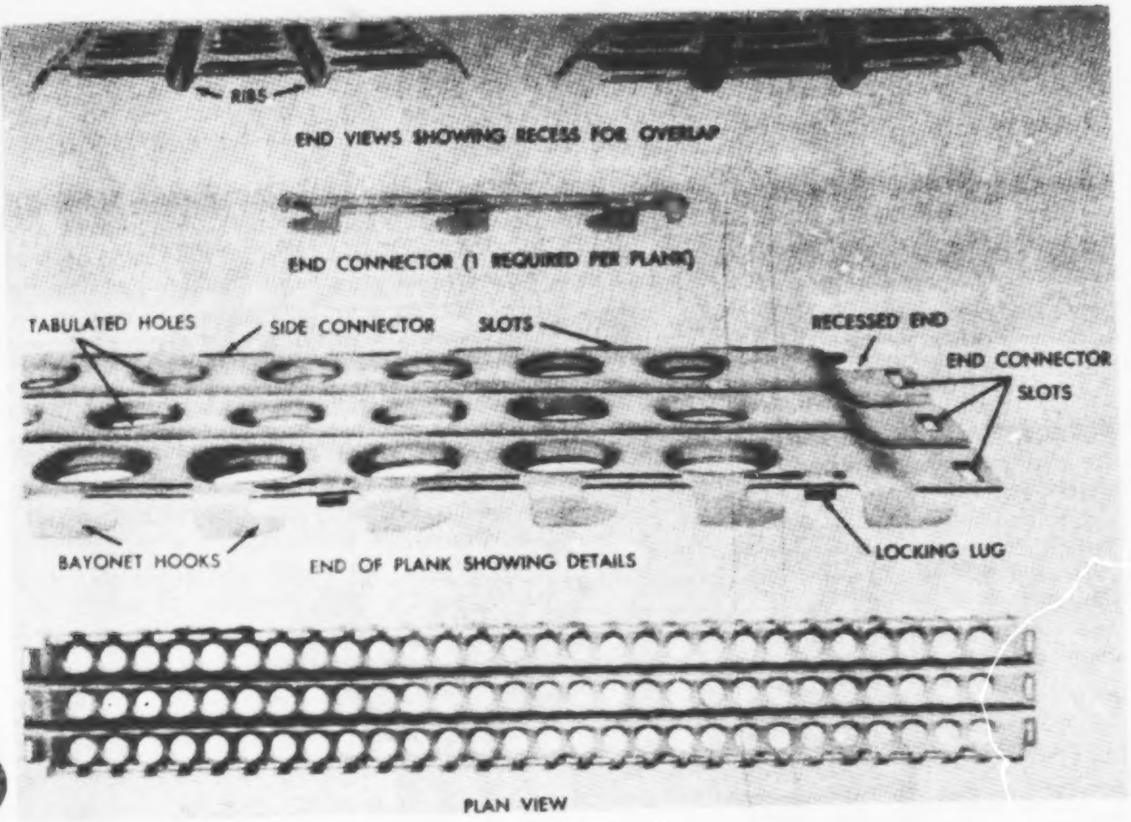

RIBS
END VIEWS SHOWING RECESS FOR OVERLAP
END CONNECTOR (1 REQUIRED PER PLANK)
TABULATED HOLES
SIDE CONNECTOR
SLOTS
RECESSED END
END CONNECTOR
SLOTS
BAYONET HOOKS
END OF PLANK SHOWING DETAILS
LOCKING LUG
PLAN VIEW

Figure 120. M6 Mat.

(3) No special equipment necessary.

(4) Easily recoverable for future use. (Each usage progressively increases the deformations due to damage, thus decreasing its effectiveness for reuse.)

(5) Width suited for road construction (25 feet wide using 2 whole and 1 half panel).

b. Disadvantages. The disadvantages of M6 mat are:

(1) High weight to surface area ratio.

(2) End connectors easily bent or lost.

(3) Not interchangeable with any other mat.

(4) Slippery when wet.

(5) Holes allow infiltration of water, causing subgrade to weaken. The holes also cause pumping in wet weather and dust in dry weather.

339. Laying M6 Mat

a. The method of laying M6 mat (fig. 121) is similar to the procedure described for M8 and M9 except that planks having bayonet lugs and connector slots along both edges can be placed in either direction across the runway. The underlap end has a longer depressed end (left end of bottom panel in fig. 120) than the overlap end (right end of bottom panel in fig. 120). In the field, it is simple to discover that the three pronged end connectors can be driven into place only when the end with the short depression overlaps the end with the long one. This means that when a crew places from left to right across a runway, the underlap end must be to the right or to the left if placing from right to left, or in the direction of placing. The end connectors are fastened on after locking the three prongs through both sets of end connector slots. A ball peen hammer is the best tool for this fastening.

b. In view of the fact that whole panels of M6 are 10 feet long and half panels 5 feet long, the computation of requirements for these mats is much simpler than, though similar to, M8 and M9.

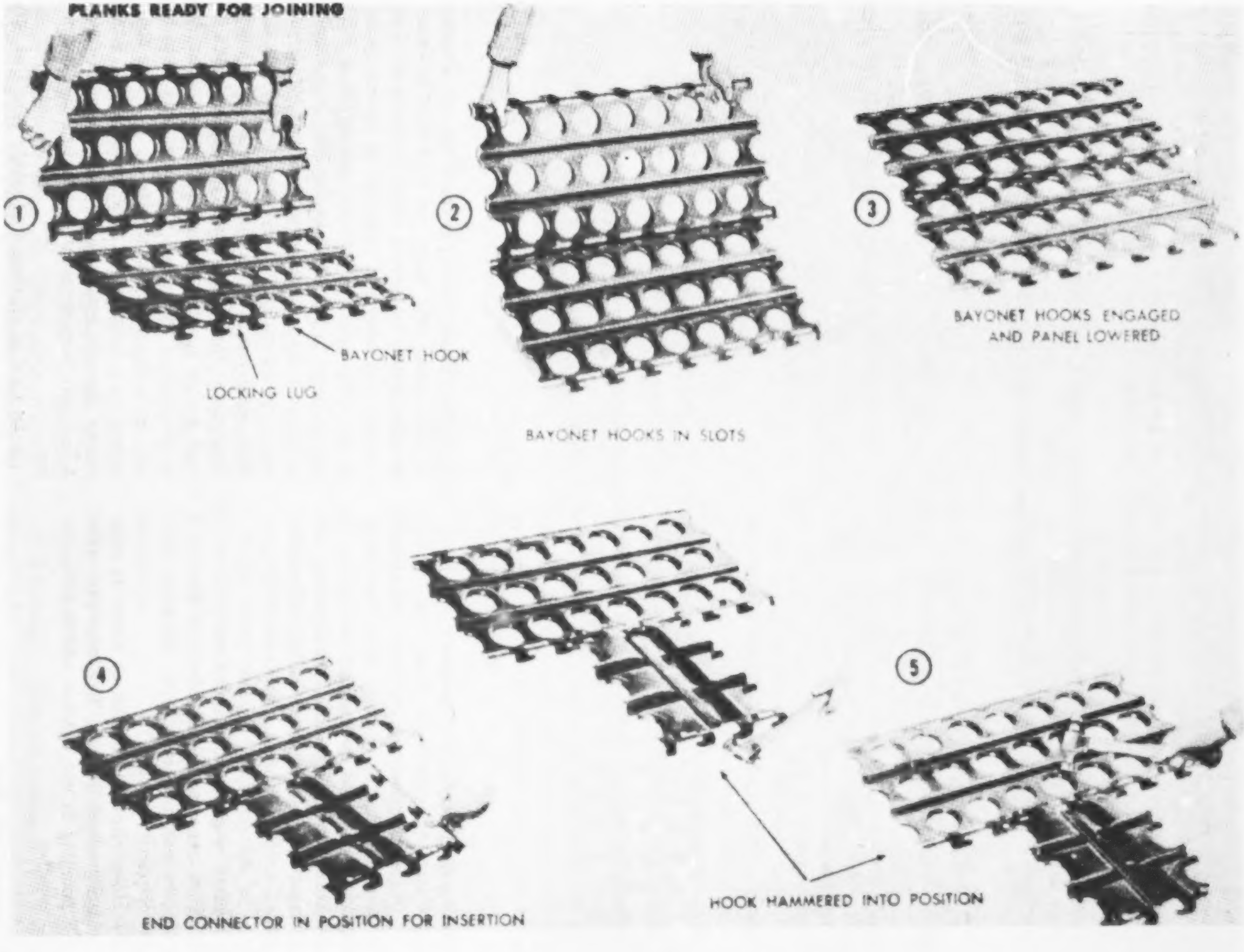

PLANKS READY FOR JOINING
①
BAYONET HOOK
LOCKING LUG
②
BAYONET HOOKS IN SLOTS
③
BAYONET HOOKS ENGAGED AND PANEL LOWERED
④
END CONNECTOR IN POSITION FOR INSERTION
⑤
HOOK HAMMERED INTO POSITION

Figure 121. Method of fastening M6 mat side and end connectors.

c. Because the L-shaped bayonet lugs point toward the underlap end of the M6 panel, and the locking lug is in the end of the side connecting slots toward the underlap end of the panel, it will quickly be discovered in the field that the M6 will go together smoothly and rapidly only one way. One run is placed all the way across the runway with the underlap end pointing toward the direction of placing the run. The next run is then placed in the opposite direction of placing the first run with the underlap end also pointing in the opposite direction. Both direction of placing and orientation in planks or panels in a run are reversed in alternate runs. This greatly slows down production, because each run must be completed before the next one can be started.

d. General principles of lapping and direction of placement apply to M6 as well as to M8 and M9; however, welding is not required where two laying teams can start on opposite sides of a given run and begin laying in the same direction, or start at opposite ends of two connected runs and start laying toward each other. Welding is necessary only where two separately constructed mats meet.

Section IV. PROTOTYPE MATS

340. MX19 Mat

a. Description. The honeycomb mat (fig. 122) is a promising prototype mat currently being tested. It consists of a foil aluminum honeycomb core bonded to top and bottom sheets of aluminum with a fiber film adhesive. Edge connectors are welded to the top and bottom sheets and bonded to the core. An antiskid surfacing is applied to the top surface. Each panel is approximately 4 feet by 4 feet and weighs 68 pounds or 4.1 pounds per square foot of usable area. A flat connector bar, 4 feet long, is an accessory used to connect the edge members.

b. Material Requirements. The material requirements are computed in the same manner as those for the M8 mat (para 324) with three exceptions.

(1) The panel size is 4.0 feet by 4.0 feet.

(2) N_w is rounded up to the next higher whole panel.

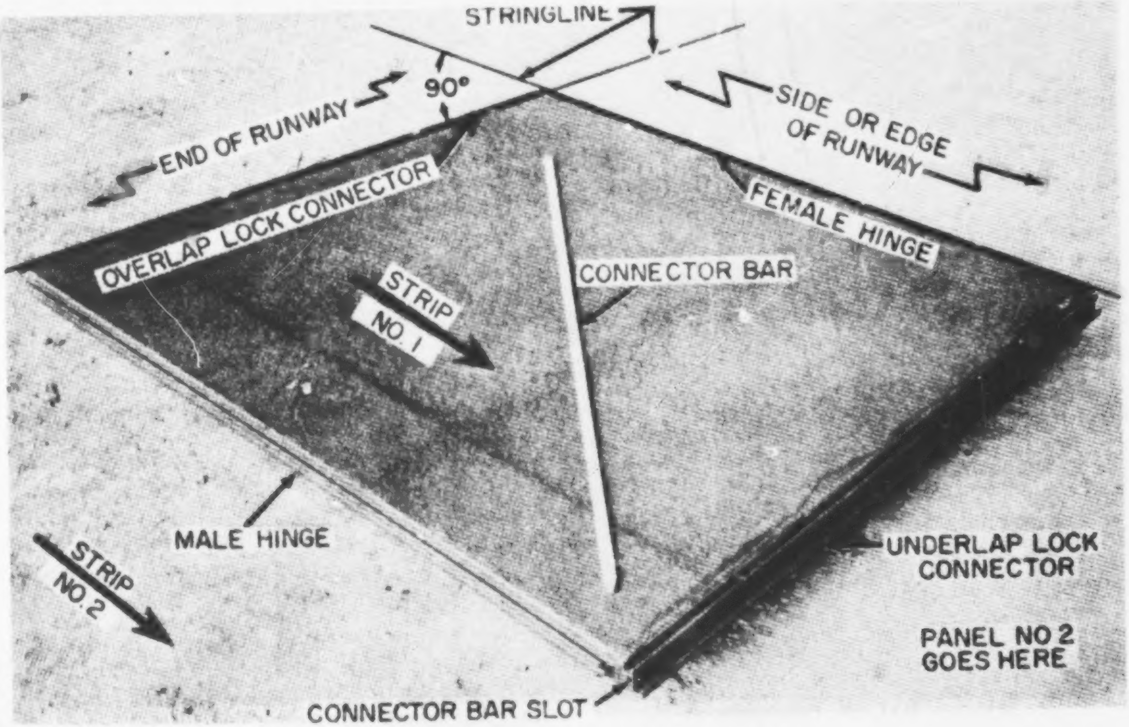


Figure 122. Position of first MX19 mat panel.

(3) Use 10 percent as a waste factor for new panels and 15 percent for old panels.

c. *Placement.* The MX19 mat is placed in a manner quite different from other mats.

(1) When standing at one end of the runway and facing the far end, the placement starts in the left corner as shown in figure 122. Note that the male hinge faces and runs parallel to the centerline. The first panel and all subsequent edge panels are alined along the stringline.

(2) The first strip is laid along the stringline at the edge of the runway. The overlap lock connector of each new panel drops into the underlap lock connector of the succeeding panel. The connector bar is slid into the slot in the lock connector joint to lock it. Figure 123 shows the bar as it is partially inserted. Care should be taken to insure that the bar is completely inserted in the slot.

(3) The second strip is critical as it controls the alinement of the entire field. The second strip is staggered so that the lock connector joint in the first strip is at the center of the panel in the second strip (fig. 123). The panels are tilted at about 45° (fig. 124) and the hook on the top of the female hinge is hooked on the male hinge. The panel is then lowered (hinged) to the ground, making certain that the lock connector joints fit. The connector bar is inserted.

(4) Once the first two strips are at least 4 or 5 panels downfield, a third strip may be started and the process is repeated across the width of the field. Another stringline down the far side of the field can be used for an additional alinement check and to mark the edge.

(5) Figure 125 depicts a completed runway section.

341. MX18B and MX18C Mats

a. *Description.* The MX18B and MX18C mats (fig. 126) are an improved version of the AM2

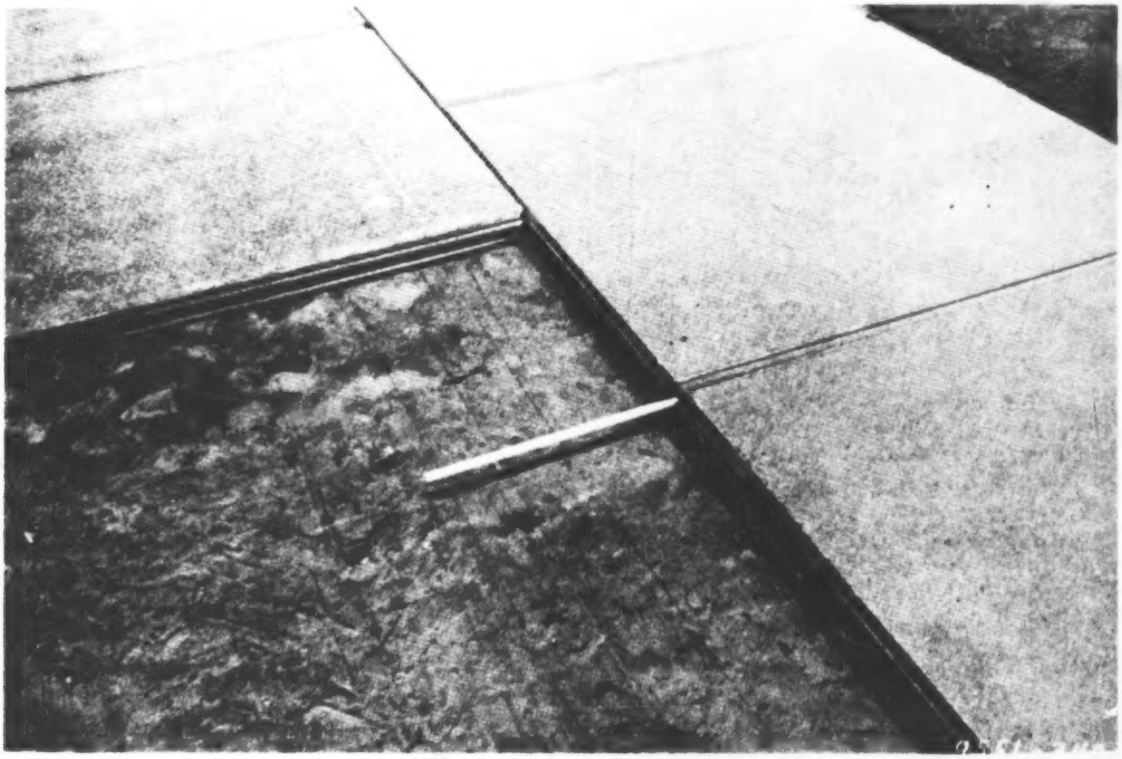


Figure 123. Partially inserted connector bar.

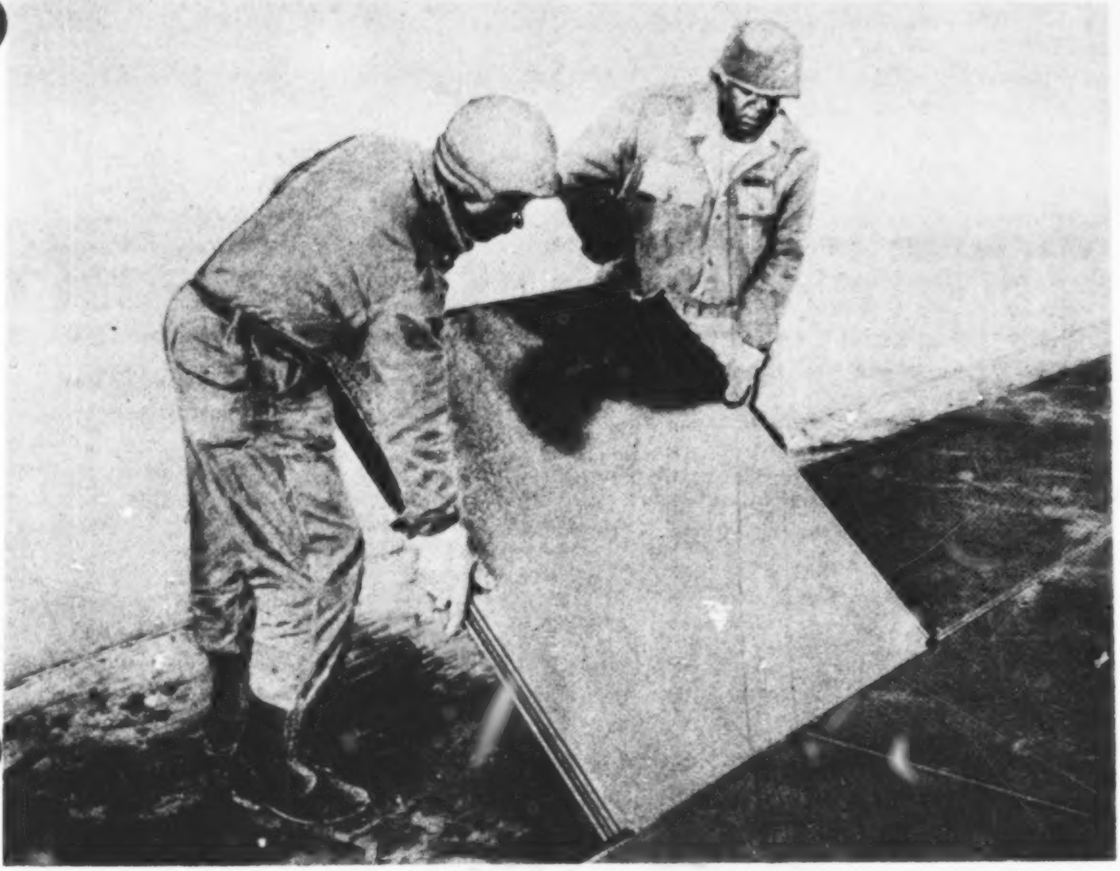


Figure 124. Laying last strip of MX19 mat.

mat developed by the Navy. Both mats are identical except for a difference in aluminum alloys. They consist of extruded aluminum planks with lapped and welded end connectors. The panels are 2 feet by 12 feet and weigh approximately 113 pounds or 4.7 pounds per square foot of usable area. A half panel is also available that is 6 feet long. A short (2-foot long) connector bar is an accessory used to complete the end connection.

b. Material Requirements. The material requirements for the MX18 mats are computed in the same manner as the M8 (para 324) with two exceptions.

(1) The panel size is 2.0 feet by 12.0 feet.

(2) Use 10 percent as a waste factor for new panels and 15 percent for old panels.

c. Placement. The method of placement is identical to the M8 method except that connections are made differently.

(1) Standing at one end of the field and facing the far end, the first panel is placed in the right corner with the male hinge facing downfield. The second panel is placed in that same run. The overlap lock connector of the new panel should fit in the underlap lock connector of the old panel. Once the lock connector joint is fitted together, the connector bar is slid into the slot to lock the joint.

(2) The second run is placed in a staggered position, the same as the M8 mat (para 328*a*). The hinge connections are made in the same manner as the MX19 mat (para 340*b*(3)).

(3) A completed MX18B runway section is shown in figure 127.

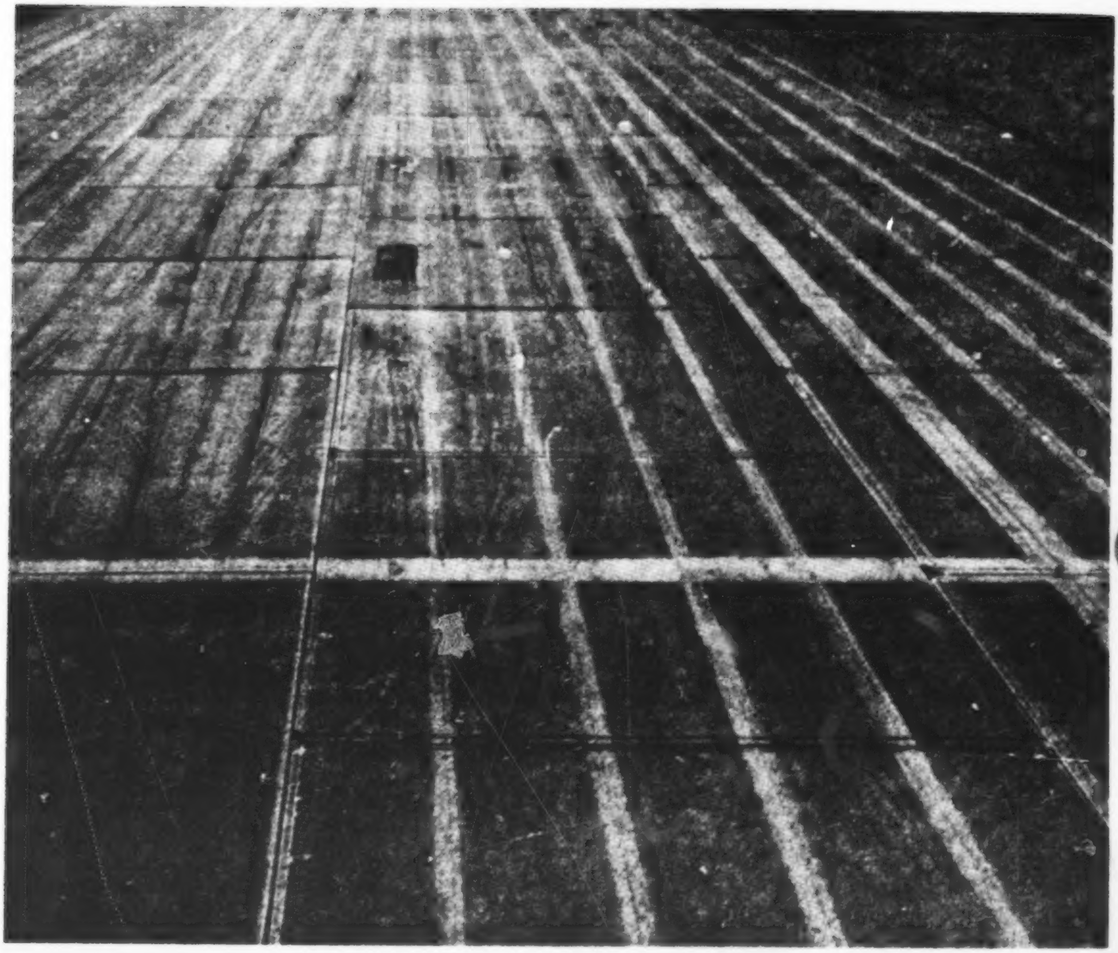


Figure 125. Completed runway section constructed of MX19 mat.

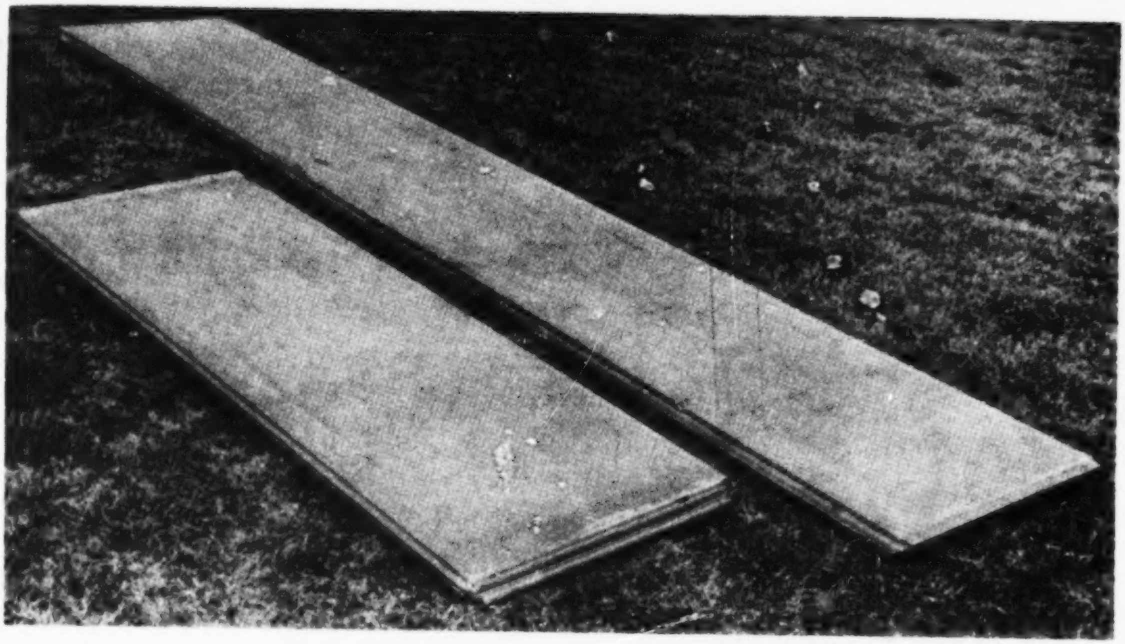


Figure 126. MX18B mat panels.

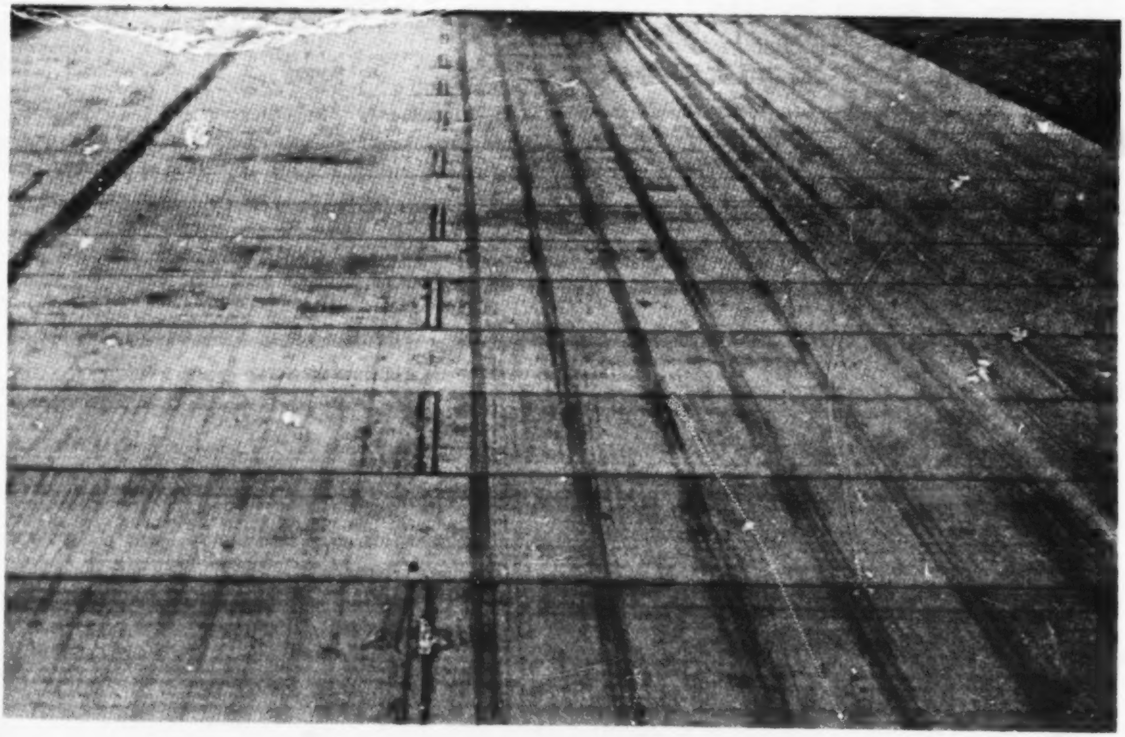


Figure 127. Completed runway section constructed of MX18B mat.

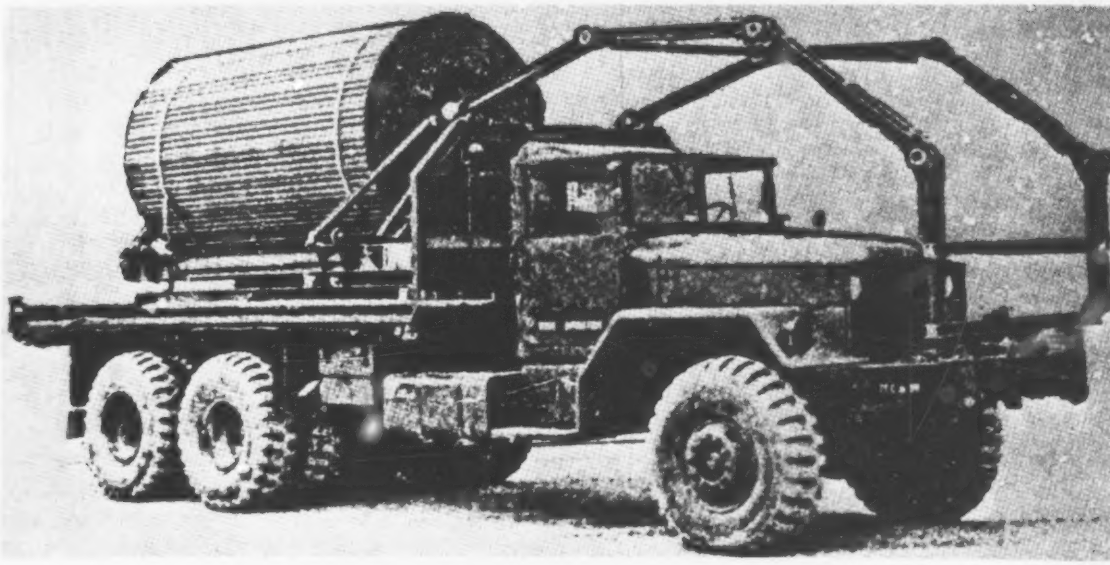


Figure 128. Class 30 Assault Trackway on 5-ton bridge truck.

342. Class 30 Assault Trackway

a. Description. The Class 30 Assault Trackway (developed by the British) consists of a connected series of extruded, corrugated aluminum planks. The planks, 11 feet long by 9 inches wide, are connected by an interlocking ball and socket longitudinal joint. Every 30 feet is a three-section replacement panel, which allows quick removal for repairs or recovery. In regular form, the trackway comes in a kit which will fit on a standard 5-ton bridge truck. The kit consists of 255 feet of trackway and a dispenser kit. Figure 128 shows the trackway mounted on a 5-ton bridge truck.

b. Placement. The trackway is placed directly from the standard 5-ton bridge truck. The exact procedures for placement operations will be covered in a separate manual when this item is standardized

Note. Although the items are similar in appearance, the American and British versions are not interchangeable.

CHAPTER 18

MEMBRANES

Section I. INTRODUCTION

343. Types

Membranes consist mainly of coated fabrics intended for use as airfield surfacing to dustproof and waterproof soil subgrades (fig. 129). Currently, there are four membranes that meet acceptable standards. Two of these are considered to be heavy duty and the other two as light duty membranes.

a. Heavy Duty Membranes. The WX17 is the heaviest duty membrane, which is capable of withstanding repeated usage by all current Army aircraft and the Air Force C–130 transport. It is manufactured from 2 ply, 5.1 ounce, neoprene-coated, nylon material and weighs 3.0 pounds per square yard. Both surfaces are pebble-grained for skid resistance. The WX12 is slightly less durable being constructed from a single ply, 8-ounce, neoprene-coated, nylon material. The WX12 weighs 2.5 pounds per square yard.

b. Light Duty Membranes. Light duty membranes are capable of withstanding repeated loads from light Army aircraft such as the 0–1 Bird Dog, U–1A Otter, and U-6 Beaver. Skid-mounted helicopters (worn skids tend to snag and tear the surface), the OV-1 Mohawk, and the CV–2 Caribou will cause failure of light duty membranes. The WX15 is a vinyl-coated, 3.2-ounce nylon fabric. The WX16 is a single ply, 5.1 ounce, neoprene-coated nylon. Both membranes weigh approximately 1.0 pound per square yard.

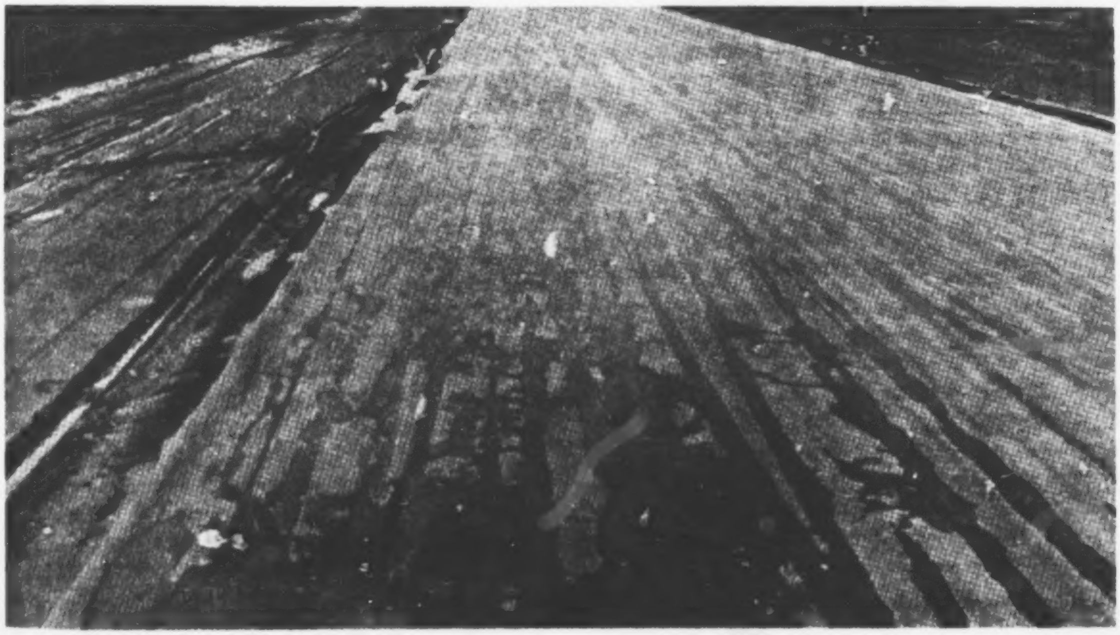


Figure 129. WX16 surface after heavy rainfall. (Note relative condition of membrane and uncovered surfaces.)

344. Packaging

Table XIX shows the various sizes of panels and rolls in which membranes have been procured. The rolls are similar in appearance to tar paper rolls. The crated membrane comes in cumbersome crates and weighs several hundred pounds. If available, a mechanical lifting device should be used to move this item.

Table XIX. Membrance Panel Sizes

Membrane	Type of package	Size	Principal use [1]
WX12	Roll	3 ft x 100 ft	Repair [2]
	Crate	30 ft x 56 ft	Panel
WX15	Crate	156 ft x 156 ft	Pad
	Crate	56 ft x 606 ft	Panel
WX16	Crate	156 ft x 156 ft	Pad
	Crate	56 ft x 606 ft	Panel
WX17	Crate	56 ft x 100 ft	Panel/Pad [3]
	Crate	156 ft x 100 ft	Panel/Pad [3]
	Crate	78 ft x 100 ft	Panel

[1] Panel denotes section of airfield runway or taxi strip. Pad denotes helicopter pad.

[2] Can also be field fabricated into panels or pads.

[3] Pads can be easily fabricated in field.

345. Fabrication

a. Plant Fabrication. Membranes are manufactured in rolls about 5 feet wide. These rolls are either chemically or electronically bonded together to form panels. The panels are then folded for insertion into crates. Often the membrane develops wrinkles when folded for long periods of time in the crates due to the difference in the residual tension in the nylon. This is similar to the flat spots that develop in nylon automobile tires after the automobile sets in one place for a period of time. These wrinkles do not affect the usefulness of the membrane to any great degree. Although cutting and patching will remove the wrinkles, stretching will remove or reduce enough wrinkles to make this measure unnecessary.

b. Field Fabrication. Field fabrication is covered in paragraph 349.

Section II. PLACEMENT

346. Job Organization

The number of men and equipment available will govern the time required for placement.

a. Manpower. The minimum size unit required is a platoon. Table XX lists the minimum number of men necessary for each task. Should more than 30 men be available within the platoon, they should be assigned to the placement crew. If more than one platoon is available, each can start at a different point along the runway.

Table XX. Minimum Crew Requirements

Crew	Number	Task
Equipment operators	6	2-motorized graders 3-truck drivers 1-jeep driver
Placement	18	Unfold, stretch and place membrane.
Joint construction	6	2-pour adhesive 4-roll adhesive on joint.

b. Equipment. Table XXI lists the minimum equipment required for efficient membrane placement.

Table XXI. Minimum Equipment Requirements

Equipment	Number
Motorized grader	2
Truck *	3
Jeep	1

* Any 6 x 6 cargo or dump truck of 2½-ton capacity or greater.

347. Site Development

After the average bearing strength of the site has been determined to be adequate for wheel loads and anticipated aircraft traffic (TM 5–330), the area should be graded to remove all vegetation, obtain a smooth working surface for placement of the membrane surfacing, and to prevent ponding of rainfall on the surfacing. When the site has been graded and sloped for drainage, V-shaped anchor ditches (para 351*a*) should be constructed at one end on the two sides of the area. Side ditches should parallel the established centerline of the runway and should be located so that the inside edges of the ditches are a minimum of 36 feet from the runway centerline for 78-foot wide membranes and 25 feet from the centerline for 56-foot wide membranes. Only one ditch that transverses the width of the runway should be constructed at this time. The remaining ditch at the other end of the membrane surfacing should not be constructed until all membrane sections have been placed and joined. This will permit access to the area by vehicles and will permit determination of the exact location of this end-anchor ditch. All soil removed during construction of the anchor ditches should be windrowed outside the runway area. Grading, sloping, and constructing anchor ditches should be accomplished with motor graders.

348. Preliminary Procedure

Vehicles will be required to transport the wooden crates of membrane to the test site. They should be large enough to provide working space on the sides and rear of the crates. The 5-ton dump truck or any other 6×6 cargo truck of at least 2½-ton capacity may be used for this purpose. The tops of the wooden crates should be removed at the site. Steel straps that secure the surfacing to the wooden platform should be cut to permit unfolding of the membrane. Once the surfacing is ready for placement, the vehicles should be positioned on the runway area so that they straddle the centerline.

349. Placement of the First Panel

Placement of the first section of membrane should be initiated by removing approximately 3 feet of the folded surfacing from the crate and placing it in the anchor ditch that was constructed transversely across the runway (fig. 130). The vehicle should then be driven slowly along the centerline of the runway, with the membrane surfacing being played off the back of the vehicle onto the ground. Care should be taken by the driver of the vehicle to insure that vehicle alinement is maintained with the centerline of the runway. Care should also be exercised by the placing crew to insure that the surfacing is placed in a straight line and flat on the ground, with all slack removed from the surfacing. When the membrane is first placed on the ground, it will consist of an accordian-folded surfacing approximately 50 to 60 inches wide and 100 feet long. After the surfacing has been unloaded from the vehicle, troops should be stationed at equal intervals along the length of the surfacing. Half of the surfacing should be unfolded (fig. 131) to one side of the area and its edge placed in the side anchor ditch. The remaining half of the surfacing should then be unfolded to the other side of the area and its edge placed in the side anchor ditch. After the membrane is alined and positioned, the initial slack is removed from the surfacing. The remaining slack is removed by placing backfill on the membrane in the end anchor ditch (fig. 132). The free end of the membrane is then pulled over the area to be surfaced. As slack is removed from the surfacing, the side ditches should be backfilled along the runway to within 6 feet of the free end of the surfacing. The side ditches should not be backfilled to the free end of the first section of surfacing, because room will be needed to join the end of the next section of surfacing to the first section.

350. Placement of Succeeding Panels

While the side ditches are being backfilled, the second section of surfacing should be unloaded on the area in the same manner as for the first section. However, the vehicle should be positioned and a sufficient amount of surfacing played off the vehicle so that the end of the second section overlaps the first approximately 24 inches. See paragraph 351, if anchors are used. The surfacing should then be unfolded and the ends placed in the anchor ditches, as was done in the first section. After the section has been positioned on the area, the ends of the first and second sections should be joined with adhesive. Adhesive for this purpose will be supplied in 5-gallon pails.

Note. Use adhesive G-580 for neoprene-coated membranes (WX12, WX16, and WX17). Use adhesive SBP-1146-A for vinyl-coated membrane (WX15). DO NOT use G-580 adhesive for vinyl-coated membranes or vice-versa.

The width of the adhesive joint should be marked on the surfacing with a chalk line or crayon for alinement purposes. The adhesive should be poured from the spout of the pail onto the surfacing and spread uniformly with long-handled rollers (fig. 133). Ample time should be allowed for the adhesive to become tacky to the touch. Usually 2 to 5 minutes are required; however, more or less time may be required, depending on weather conditions.

Note. Construction of the adhesive joints during inclement weather should not be attempted, as the adhesive will ball up and not adhere to the membrane surfacing.

When the adhesive becomes tacky, the overlapping ends of the sections should be placed in contact and the joint allowed to set for 10 to 15 minutes. Then the joint should be rolled with a rubber-tire vehicle (jeep) to remove air pockets and excessive adhesive. After the adhesive lap joint has been constructed, slack should be removed from the surfacing and the side ditches backfilled to within 6 feet of the free end of the section. Placement of additional sections of surfacing and construction of the ad-

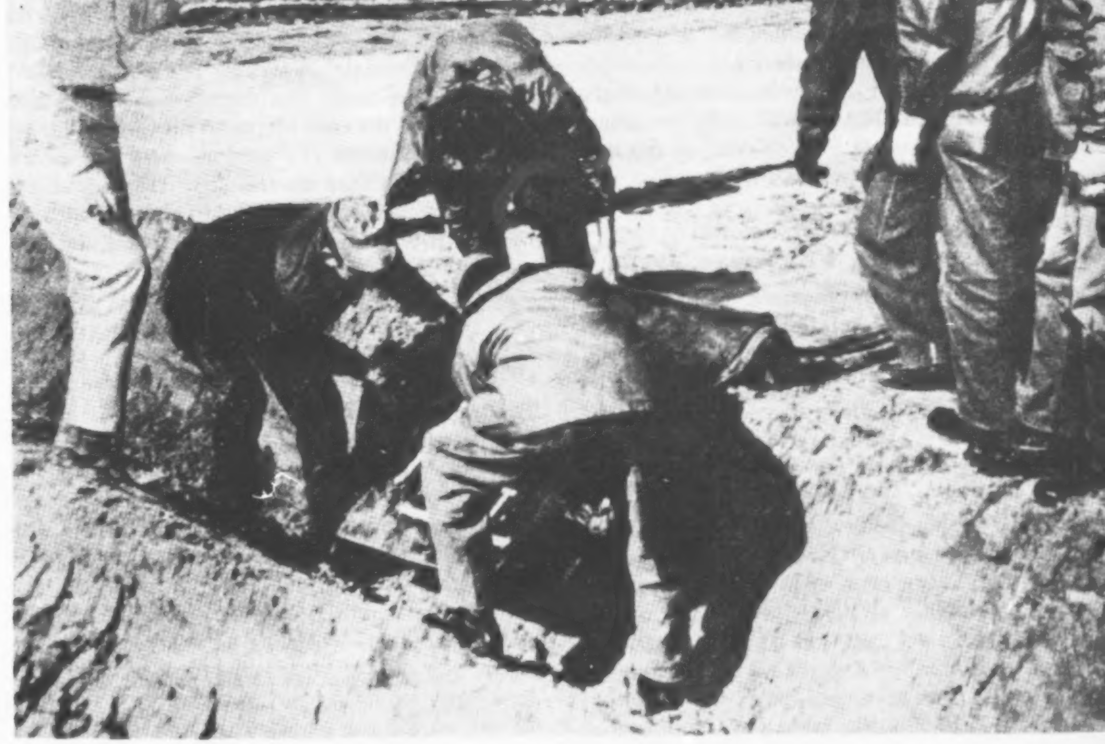


Figure 130. Placing membrane in anchor ditch.

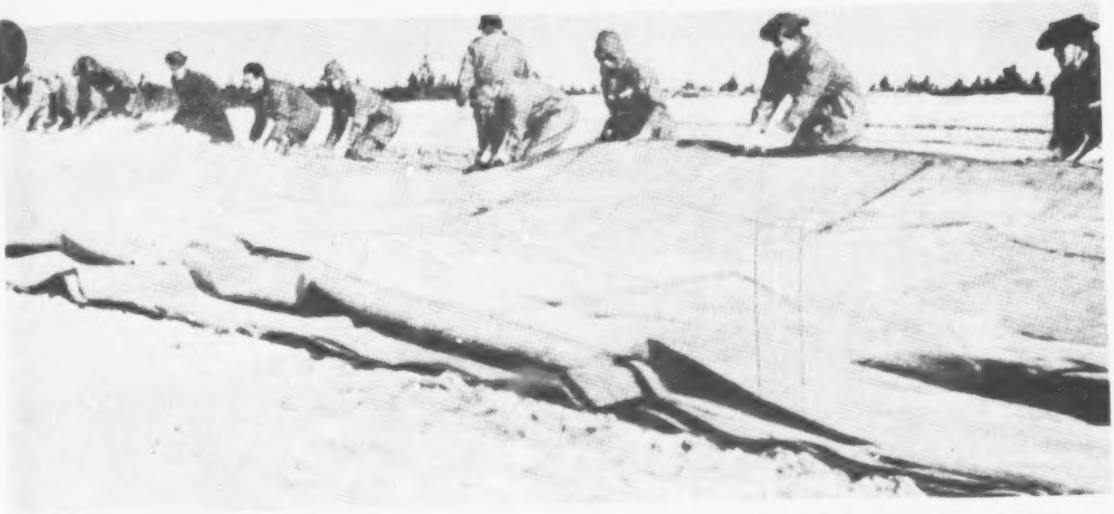


Figure 131. Unfolding membrane from centerline toward anchor ditch.

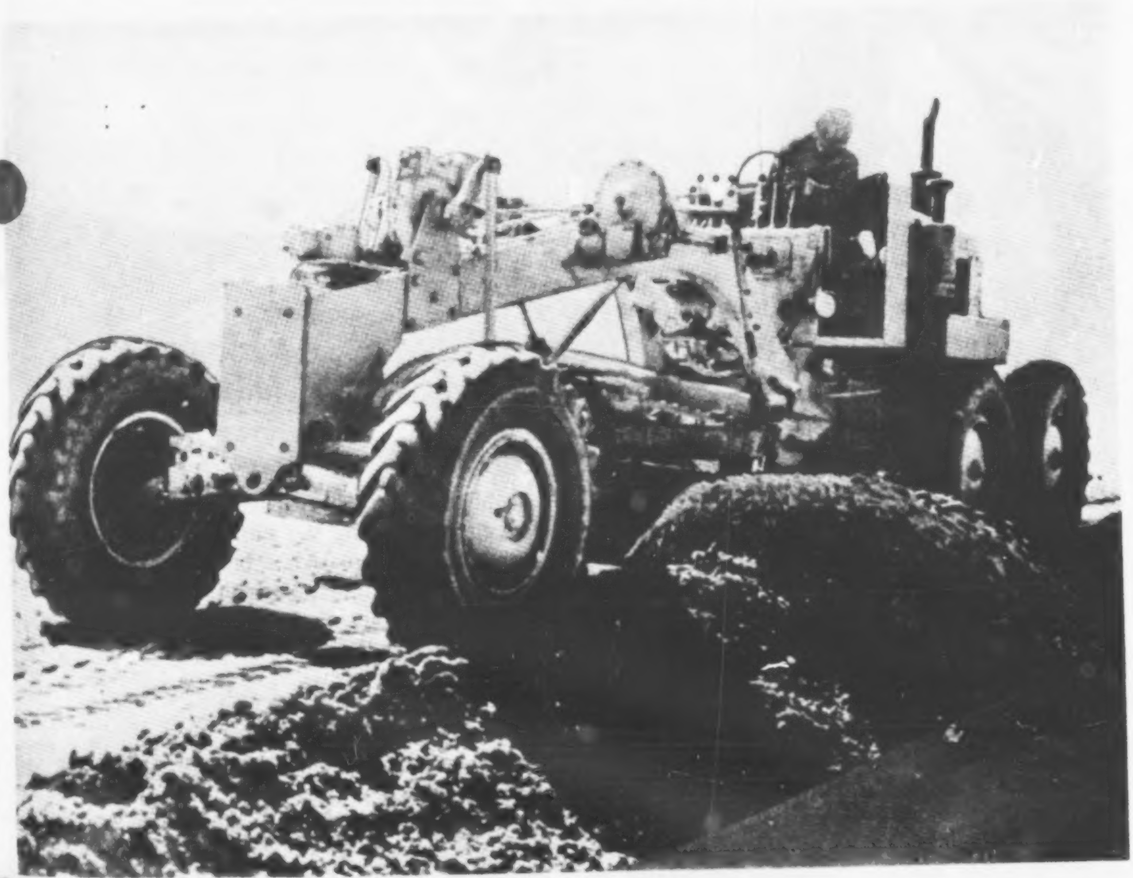


Figure 132. Backfilling anchor ditch with motorized grader.

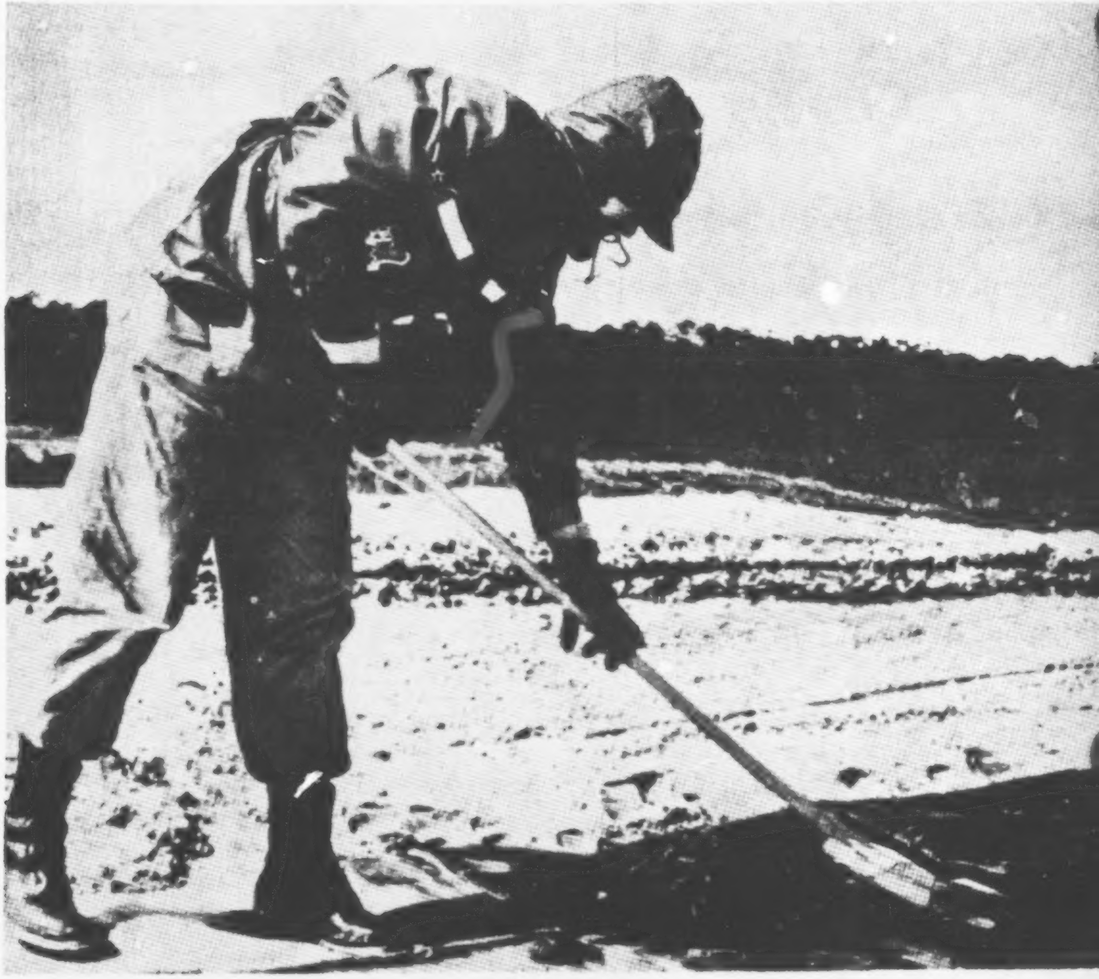


Figure 133. Spreading adhesive with long-handled roller.

hesive joints should be accomplished in the same manner as that described previously. After the adhesive joint has been constructed and slack has been removed from the last section of surfacing, the location of the end anchor ditch should be determined. The end of the last section of surfacing should then be folded back upon itself so that the anchor ditch can be constructed with the motor grader. After the anchor ditch has been constructed, the surfacing should be pulled as tightly as possible, placed in the ditch, and backfilled. All of the ditches should then be compacted with the motor grader or with the transport vehicles. This not only compacts the ditch, but also increases the tension on the membrane. If the motor grader is used, care should be taken to prevent the grader blade fro snagging or cutting the surfacing. When the su facing has been placed, a broken white or yello line should be painted along the centerline, in add tion to solid lines along the sides. After installa tion of safety devices and a final inspection, th airstrip is ready for use.

351. Anchorage

Anchorage methods are broken down into tw groups: perimeter and interior.

a. Perimeter Anchorage. Anchorage around th edge (perimeter) of the landing strip is best ob tained by V-ditches (fig. 135). The depth of th V-type ditches should be at least 2 feet and pref

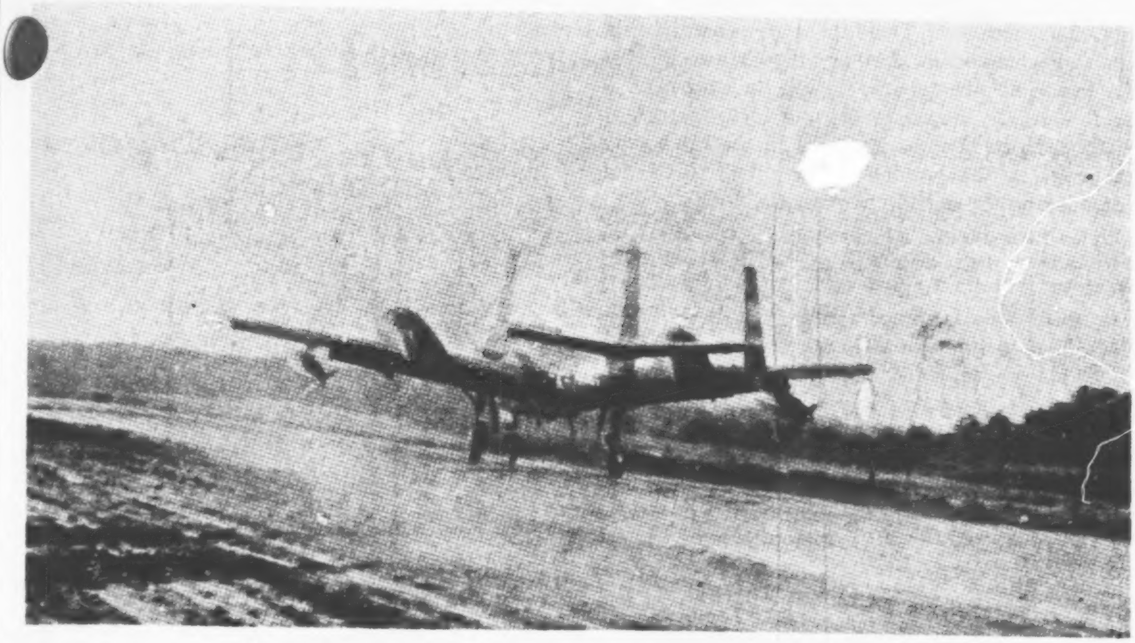


Figure 134. OV-1 Mohawk landing on WX17 membrane surfaced runway.

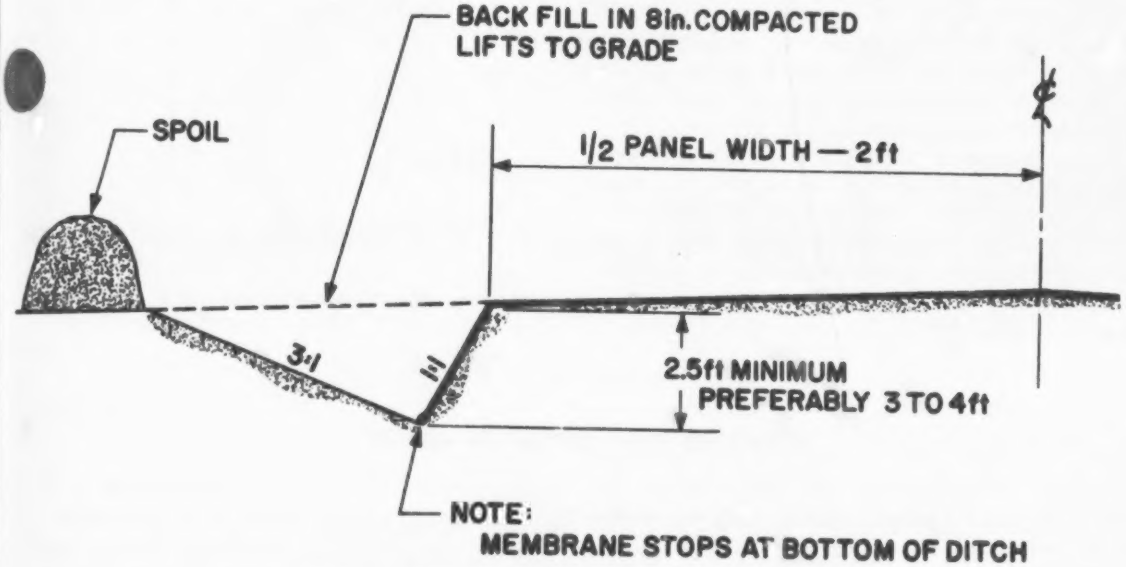

BACK FILL IN 8In. COMPACTED LIFTS TO GRADE
SPOIL
℄
1/2 PANEL WIDTH — 2ft
3:1
1:1
2.5ft MINIMUM
PREFERABLY 3 TO 4ft
NOTE:
MEMBRANE STOPS AT BOTTOM OF DITCH

Figure 135. Correct method of anchor ditch construction.

ably 3 or more feet. The ditches are constructed in the same manner as drainage ditches except that the inside, not the outside, slope is the steepest. All spoil must be moved to the outside edge of the ditch. The membrane is placed in the ditch with the edge in the bottom of the ditch. It is not extended up the outside bank of the ditch.

Note. Extending the membrane up the far side of the ditch causes surface runoff to be retained in backfill resulting around the perimeter of the field.

The membrane is pulled tightly and the ditch is back-filled in approximately 8-inch lifts. After each lift is placed, the grader should be allowed to compact the fill. This not only increases the compaction, but also tightens the membrane.

Caution: The grader operator should exercise great care to insure that the blade does not tear the membrane. The completed fill should be smoothed off so that proper drainage can be maintained.

b. Interior Anchorage. Interior anchorage should be used only in large areas. The anchors present a serious maintenance problem after extended usage. Anchors are usually placed at interior joints between panels. When anchors are used, the overlap should be 2.0 to 3.0 feet. The anchors are constructed as shown in figure 136. They should be thoroughly inspected for burrs and warped heads before using. The anchors are then driven through the bottom layer of membrane about 2.0 feet back from the edge (fig. 137) taking care not to warp the head while driving. When the anchors are completely driven into the ground, the adhesive is applied and the top layer folded across the joint as in a standard joint.

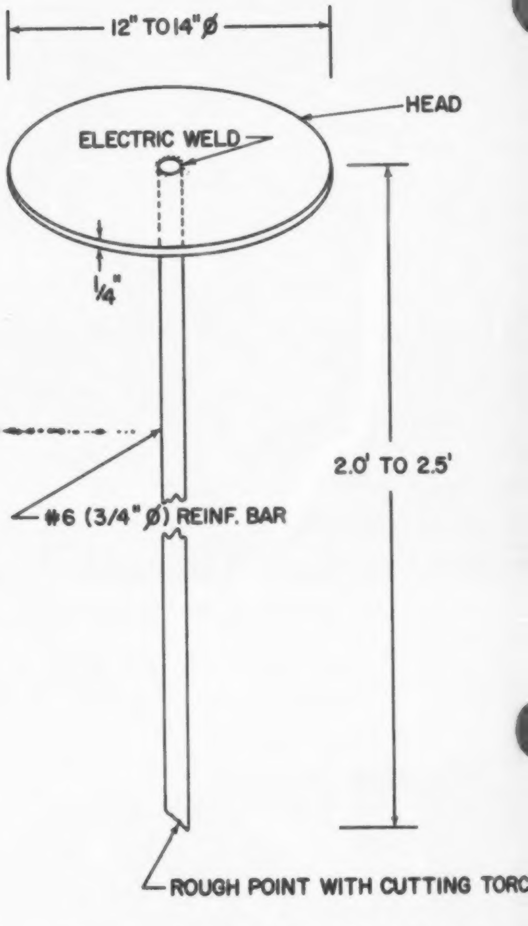


Figure 136. Method of making interior anchor.

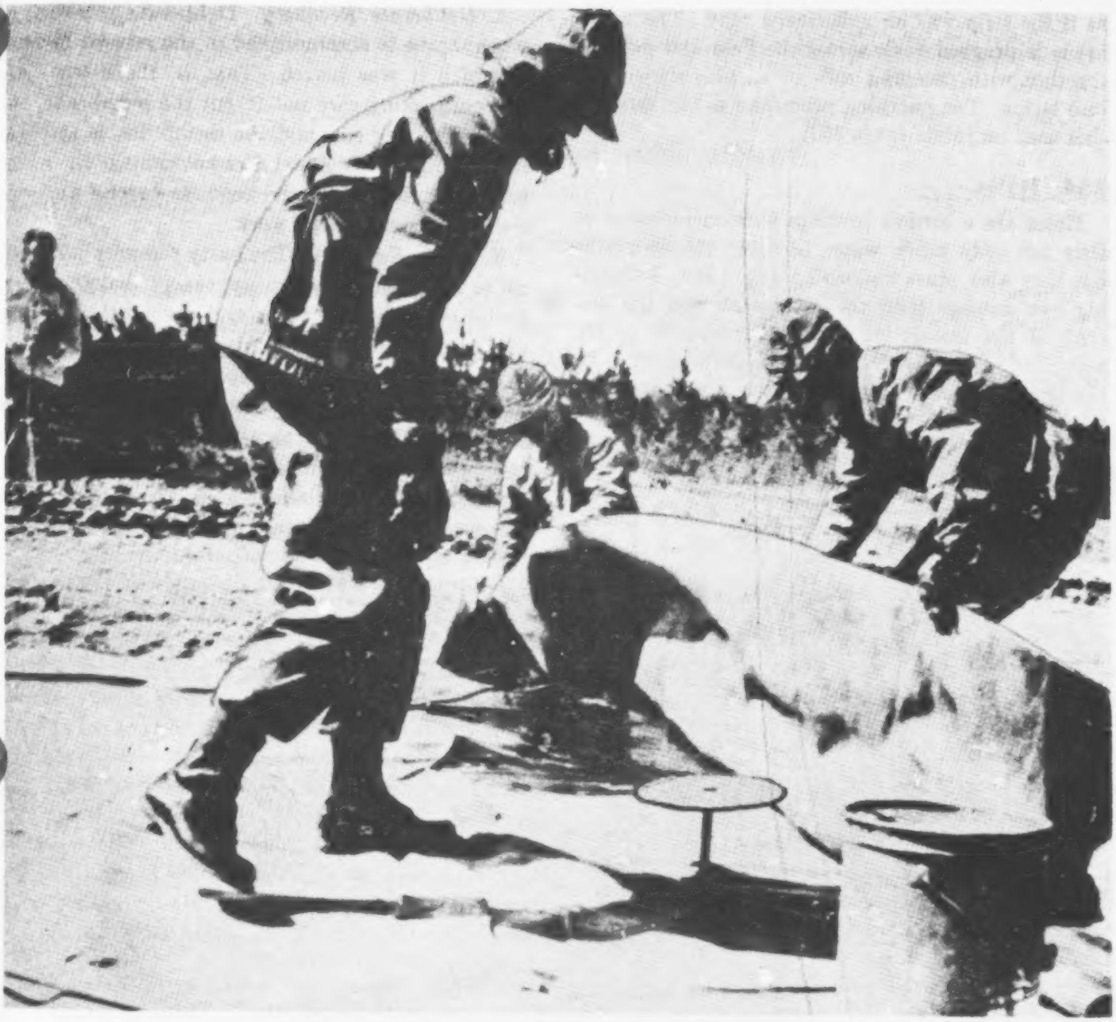


Figure 137. Placing interior anchor at joint.

Section III. REPAIR AND RECOVERY

352. Inspection

Daily inspections of the surface should be made. Preventive maintenance is necessary for the membrane to do its job for any appreciable period of time. The inspector should look for ruts, holes, and blocked drainage.

353. Rutting

Since the membrane is placed directly on the soil, ruts should be located, noted, and removed as soon as possible.

a. Low CBR Soils. Ruts are easily removed on most low CBR soils by running a 5-to 8-ton tandem roller or a 13-wheel, pneumatic-tired roller over the high spots, forcing the material, laterally, into the low spots. If this does not work, the procedure for high CBR soils must be followed.

b. High CBR Soils. Removal of ruts from high CBR soils is difficult and time consuming. The membrane is cut about 18 inches back from the edge along the anchor ditches around both ends and one side. The membrane is then dragged across the field to the attached side. The ruts are then repaired as if the strip was an unsurfaced road. The membrane is dragged back across the field and patched together with patching rolls or surplus panels cut into strips. The patching procedure is the same as that used for joints (para 350).

354. Holes

Holes are a serious problem with membranes as they not only allow water to enter the subgrade, but they also cause ballooning (fig. 138). Ballooning can damage both the membrane and the aircraft if the membrane becomes entangled in the propeller. The area around the hole should be thoroughly cleaned and the patch applied in the same manner as joint construction (para 350).

355. Recovery

Membranes may be recovered for future use by two methods: deliberate and hasty.

a. Deliberate Recovery. Deliberate recovery o a membrane is accomplished in the reverse manne in which it was placed. That is, the ditches are dug out, taking care not to cut the membrane, the field joints are cut, and the membrane is refolded and crated. This method does not damage the membrane, but it is slow and requires careful supervision and a great deal of work.

b. Hasty Recovery. The hasty recovery is identical to the deliberate recovery, except that the membrane is cut at the edges and the portions in the anchor ditches are left in place. The hasty method is faster and requires less supervision, but the width and length of the membrane are shortened by the amount left in the anchor ditches. The shortened membrane can be reused on another field with narrower runway requirements or as a taxiway o warm-up apron surfacing.

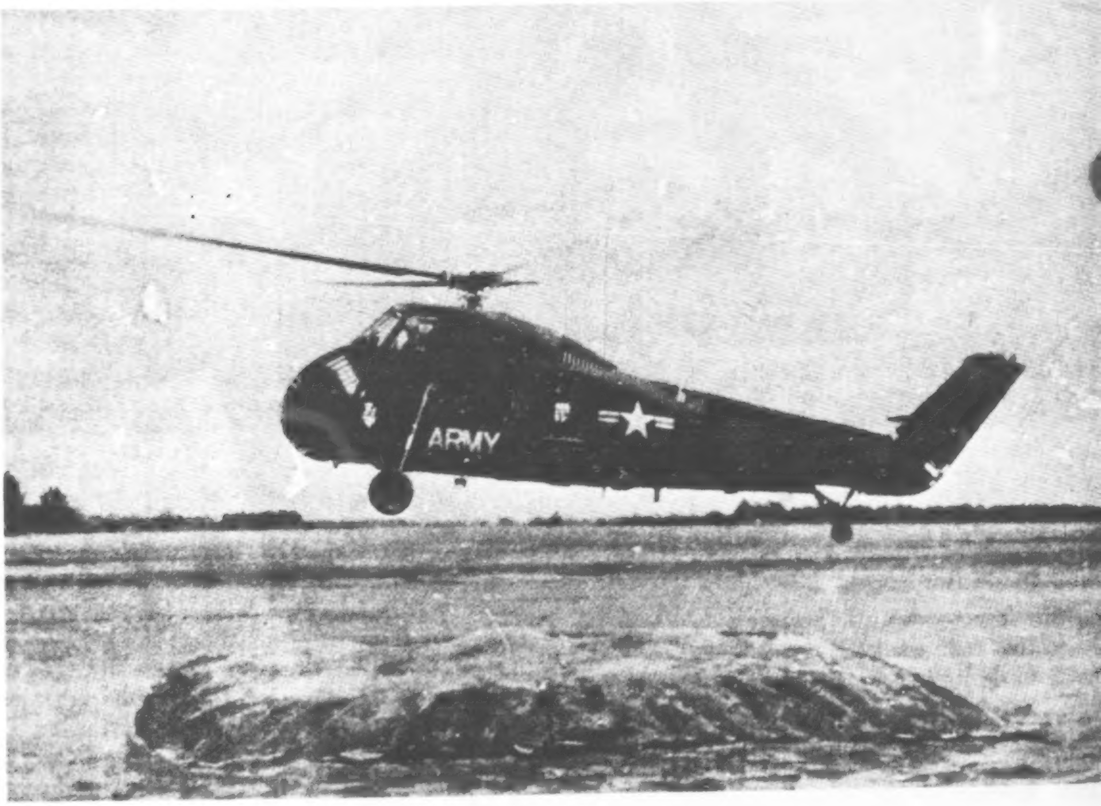


Figure 138. Membrane ballooning.

CHAPTER 19

EXPEDIENT ROADS AND REPAIR

Section I. HASTY ROADS

356. Expedient Road Construction

a. Methods. Expedient roads are usually constructed as an emergency measure for crossing difficult terrain. Any available material or method may be used that will provide a temporary surface. Sandbags, wet sand, treadway decking from floating bridges, rocks, rubble, brick, and canvas may be used as expedients. Dust palliatives may be used either as a temporary wearing surface or as a base. The importance of subgrade preparation for expedient roads is discussed in paragraph 322.

b. Types. The two types of expedient roads are hasty and heavy. Hasty expedient roads are built in a short time to last only a few days. They are used mostly to cross a terrain obstacle such as a beach or marsh. For breaching operations, beach landings, and roadblock detours, hasty expedient roads must be laid rapidly and easily. Often they must be laid during darkness. To meet these conditions, they must be light, simple to lay, and not bulky. Heavy expedient roads are used because of special ground conditions or lack of standard road construction material. They are built to last until a durable standard road can be constructed; therefore, they require longer time for construction.

357. Cross-Country Tracks

Cross-country tracks may be constructed by removing main obstructions with handtools or mechanical equipment, followed by passage of some tracked or multiwheeled vehicles. This type of road can carry heavy traffic in dry weather, although motor convoys may set up considerable dust clouds that will aid enemy observation of military movements. If such is the case, enemy aircraft and artillery may deny the use of the route except for night operations. Dust palliatives may be used to reduce the chance of observation.

358. Army Track

To help vehicles in passing over loose sand and wet ground, a portable timber mat known as army track (or tread) may be used. It is prepared with 4- by 4-inch or 6- by 6-inch timbers, about 9 feet long, which are laced together with cable or threaded onto a cable which passes through holes near each end of the timber (fig. 139). To keep the timbers spaced 12 to 14 inches, such holes are bored at an angle of 45° to the long axis of each timber. The cables are then securely anchored at each end. The track can be filled in between the timbers with the best material available to provide traction and a smoother riding surface.

359. Chespaling Mat

Chespaling-mat roads are composed of a series of mats 6½ by 12 feet, or larger. The mats are made by placing small saplings 6½ feet long and about 1½ inches in diameter, 3 inches apart, and wiring them together with chicken wire mesh or strands of heavy smooth wire (fig. 140). A chespaling road is constructed by laying mats lengthwise with a 1-foot side overlap at the junction of the mats (fig. 141). The resulting surface is 12 feet wide. Unless laid on wet ground, this type of road requires periodic wetting down to retain its springiness and to prevent splitting. It also requires extensive maintenance.

360. Bamboo Mats

In some localities, bamboo mats may be fabricated and used for roads. The mats are made by splitting 2-inch bamboo rods and weaving them as shown in figure 142. The bamboo should be soaked before weaving and kept moist while in use. On firm ground or sand, the mats remain serviceable for 3 or 4 months; on muddy ground or unstable soil, the mats pass as many as 1,500 vehicles before becoming unserviceable. They are excellent for beach roadways and for roads out of fords. The bamboo mats are laid on the ground with the long dimension perpendicular to the direction of traffic. They are staked securely to the ground and adjacent mats are wired together.

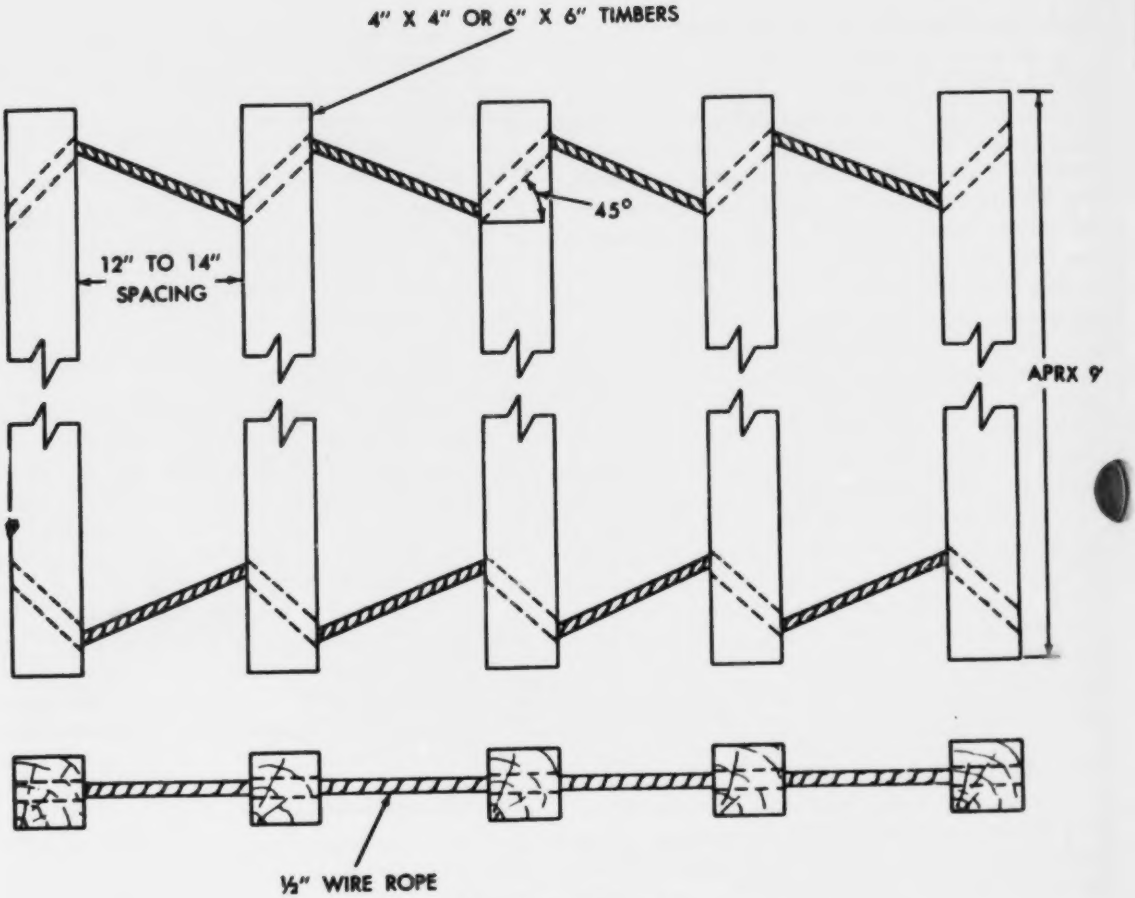

4" X 4" OR 6" X 6" TIMBERS
45°
12" TO 14" SPACING
APRX 9'
½" WIRE ROPE

Figure 139. Army track.

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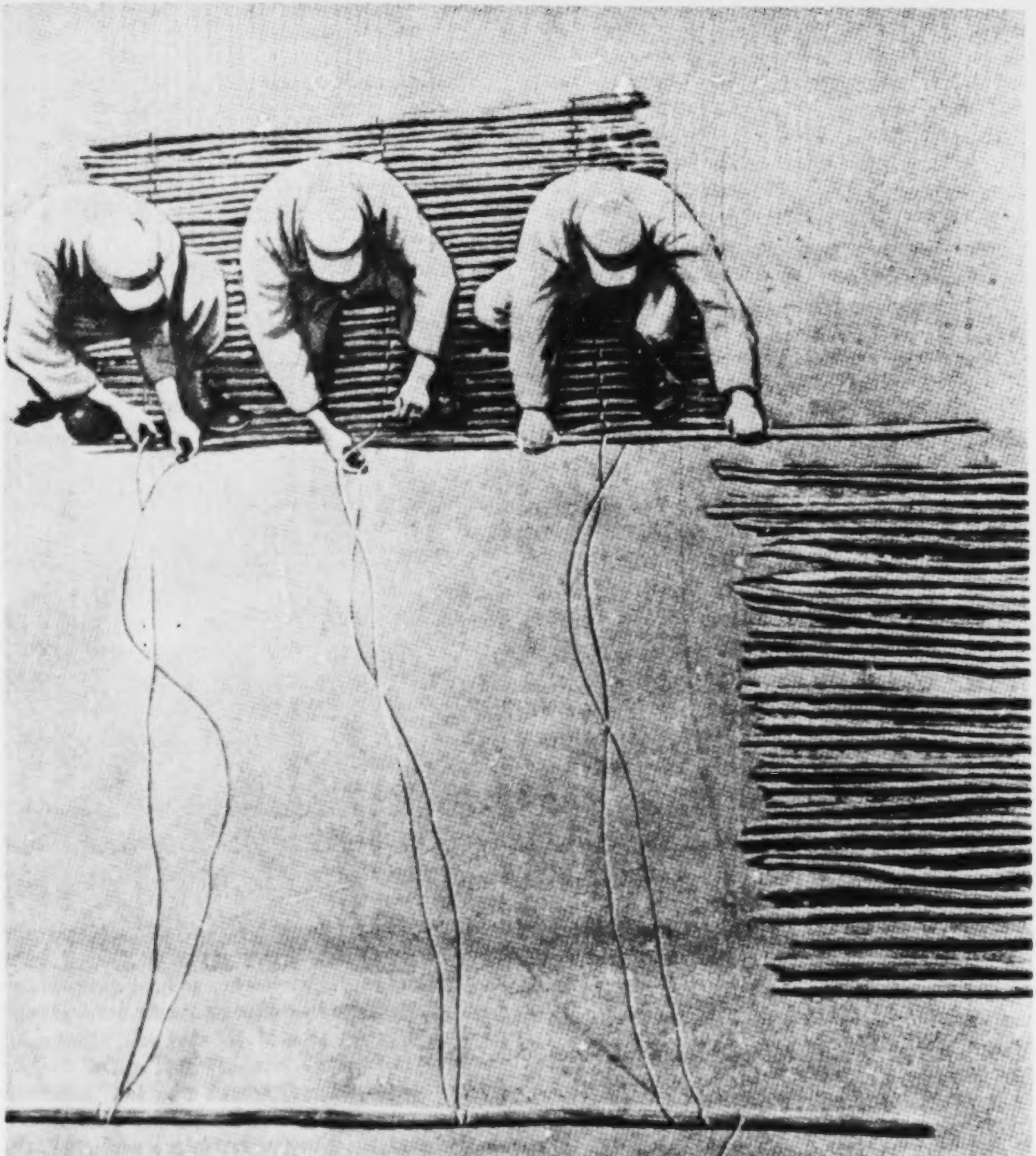


Figure 140. Constructing a chespaling mat.

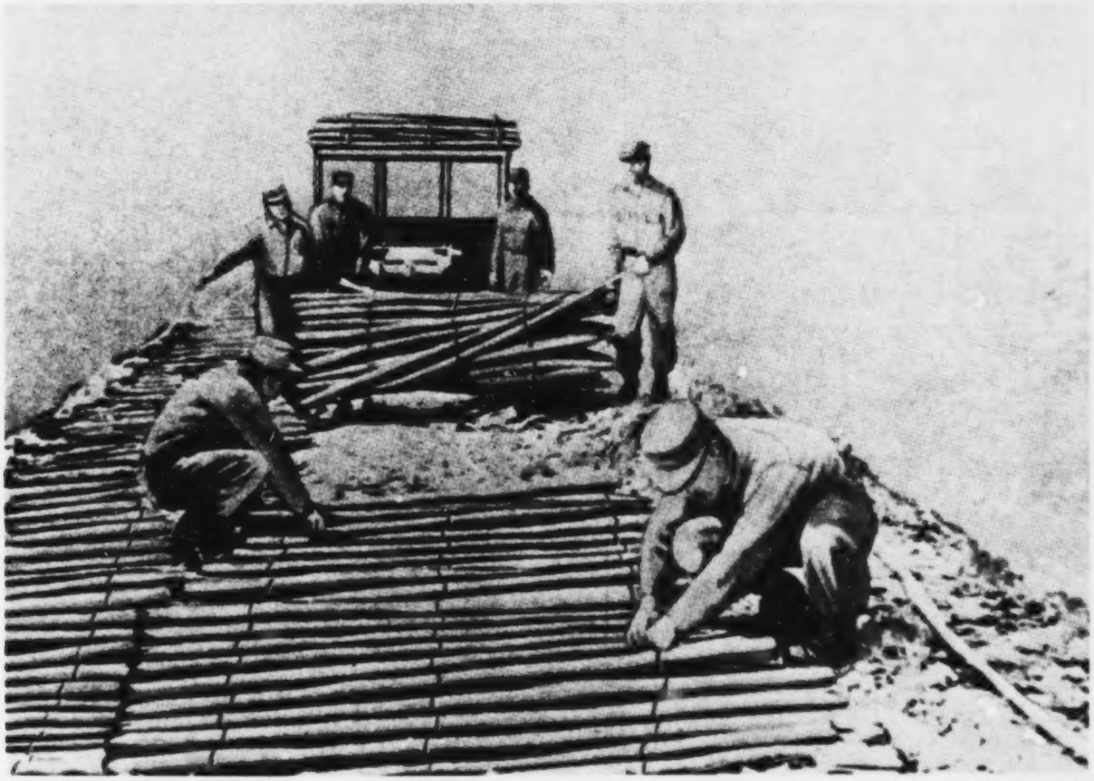


Figure 141. Laying a chespaling-mat road.

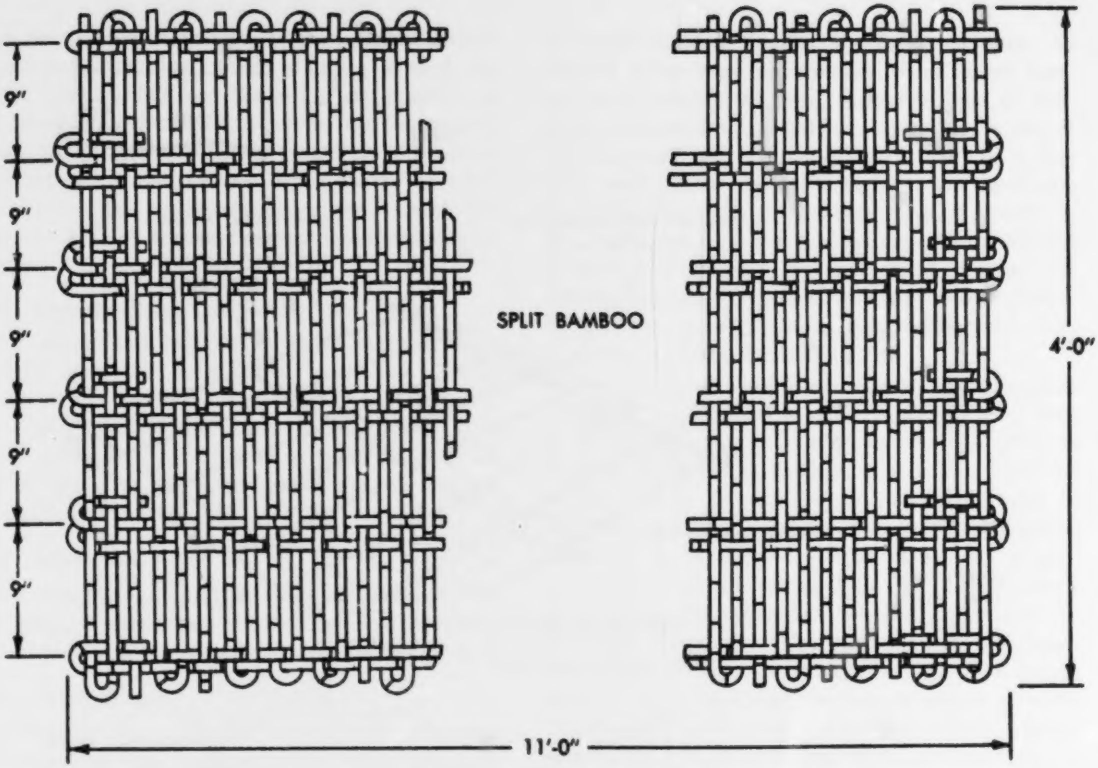


Figure 142. Construction details for a bamboo mat.

Section II. SOMMERFELD TRACK

361. Introduction

Although Sommerfeld track is not a standard supply item, it was a British item in World War II and it may appear again in theaters of operation. It is a light, easily laid track, highly suitable for beach roadways in landing operations. It is made of prefabricated wiremesh netting and steel bearing rods (fig. 143). The rods are bent at the ends to form loop 5 inches long through which steel flats are threaded. The rods stretch the netting without affecting its flexibility for rolling. A better roadway results if four out of every five transverse bearing rods are removed. Otherwise, under normal traffic, they bend up at their ends and catch in the undercarriage of vehicles. The removed bars can be bent into U-shapes and used as extra pickets. Half-inch wire rope may be substituted for the transverse bars. Special buckles, six for each joint, are used to connect the end rods of successive rolls of mesh at the transverse joint. Pickets are used to anchor the track. Two types of pickets, heavy and light, are supplied with the track in the proportion of 25 percent heavy pickets and 75 percent light pickets. The heavy pickets are better for use in loose sand and gravel where traffic is heavy. The weight of 100 yards of assembled track is about 2½ tons. Flexible duckboards, 9 by 3 feet, are used with Sommerfeld track to give added depth to the structure. They are laid end-to-end and secured with ordinary pickets. In addition to these duckboards, anything from burlap to corduroy can be placed under the track to increase depth and flotation in varying degrees.

362. Laying Sommerfeld Track

To construct a road with Sommerfeld track, the mat is rolled out on the ground. Flats and rods are placed and the mat staked by placing one picket at each overlap of steel flats and at the center of each transverse rod. When the track is laid, it

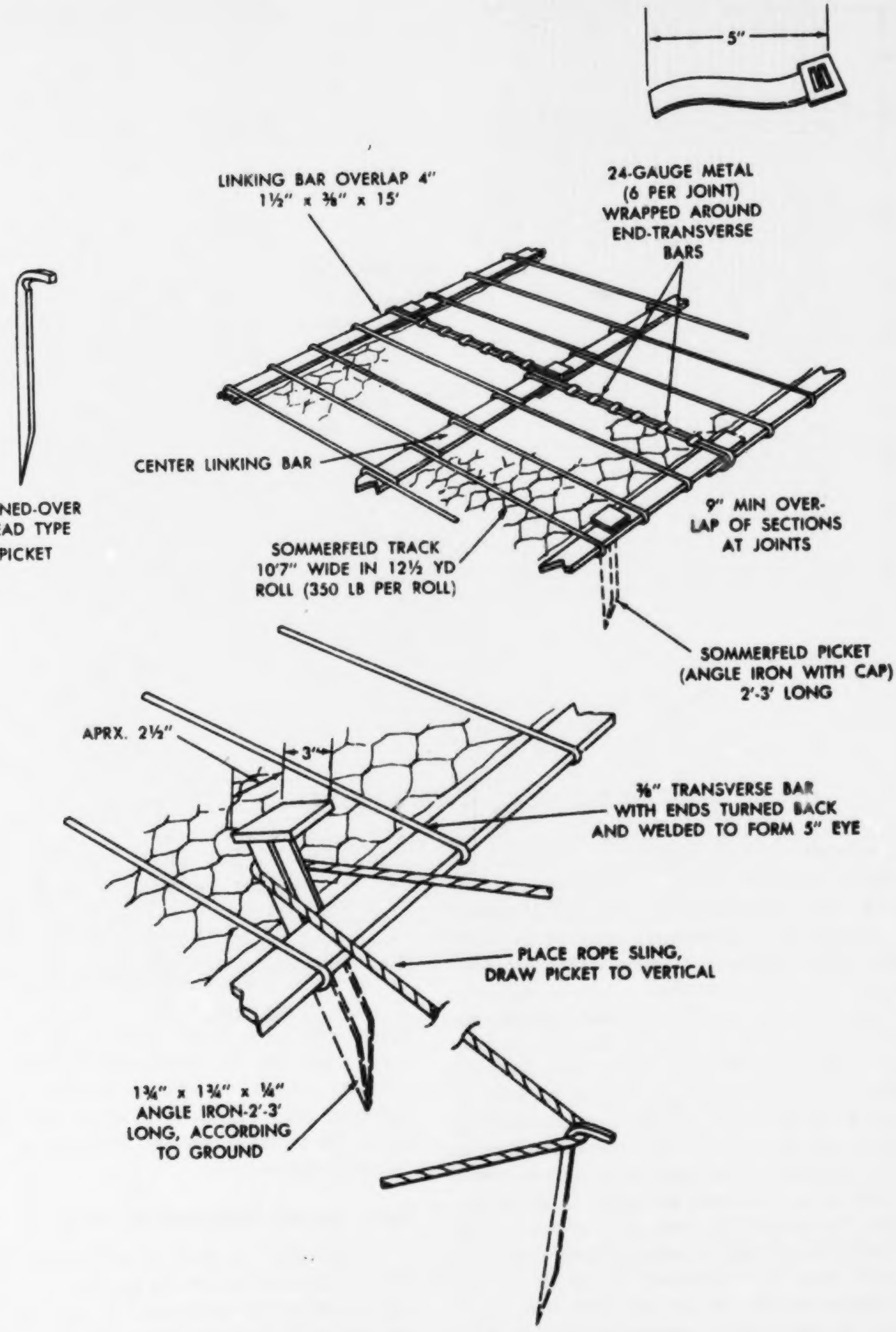

5"
LINKING BAR OVERLAP 4"
1½" x ⅜" x 15'
24-GAUGE METAL
(6 PER JOINT)
WRAPPED AROUND
END-TRANSVERSE
BARS
CENTER LINKING BAR
TURNED-OVER
HEAD TYPE
PICKET
9" MIN OVER-
LAP OF SECTIONS
AT JOINTS
SOMMERFELD TRACK
10'7" WIDE IN 12½ YD
ROLL (350 LB PER ROLL)
SOMMERFELD PICKET
(ANGLE IRON WITH CAP)
2'-3' LONG
APRX. 2½"
3"
⅜" TRANSVERSE BAR
WITH ENDS TURNED BACK
AND WELDED TO FORM 5" EYE
PLACE ROPE SLING,
DRAW PICKET TO VERTICAL
1¾" x 1¾" x ¼"
ANGLE IRON-2'-3'
LONG, ACCORDING
TO GROUND

Figure 143. Component parts of Sommerfeld track.

must be stretched taut. To do this, pickets should be started with their heads slanting toward the center, with the flat over the picket and slightly off the ground. As the picket is driven into the ground, a rope sling is placed over the picket and the picket pulled to a vertical position. This draws the mesh taut. Since the mesh netting is not strong, the picket must bear against the steel flats or transverse rods.

363. Sommerfeld Sandwich

For use on soft beaches or under water, a Sommerfeld sandwich is made by inclosing flexible duckboards between two layers of Sommerfeld track. The upper layer of the sandwich enables the tires of the vehicles to grip; the lower layer gives depth and flotation so the structure keeps its surface above the sand or mud.

364. Monkton Pack

Monkton pack is Sommerfeld track folded in 7½-foot lengths with the steel flats already threaded (fig. 144). Its chief advantage is speed of laying.

365. Wire Mesh

a. Introduction. Chicken wire, chain-link wire mesh, cyclone fence, and expanded metal lath may be used as road expedients in sand. They are unsatisfactory on muddy roads. The effectiveness of any one of the mesh-type expedients is greatly increased by the addition of a layer of burlap or similar material underneath to help confine the sand. With the lighter forms, such as chicken wire or cyclone fence, this is mandatory. A sandwich type of construction is often used; one layer of wire mesh, one of burlap, and a second layer of wire mesh, etc. The effectiveness of any type of wire mesh expedient depends on its being kept taut. To this end, the edges of the wire mesh road must be picketed at 3- to 4-foot intervals. Diagonal wire, crossing the centerline and attached securely to buried pickets, fortifies the lighter meshes. As with all other road surfaces, the more layers used, the more durable the road. Likewise, just as subgrade preparation has much to do with the life of any standard road, it also affects the life of a wire mesh road. Most wire mesh surfaces are expedients in the strictest sense of the word. Applied directly to the subgrade, they provide passage for a limited number of vehicles for a short time. Longer life can be obtained by the methods noted above: proper subgrade preparation, multilayer or sandwich construction, and frequent staking.

b. Chain-Link Wire Mesh. Chain-link wire mesh (fig. 145) is composed of a 6- to 10-gage wire with 1- to 1½-inch mesh. One of its common types is cyclone fence. It is usually laid over a layer of burlap and a 3- to 10-gage strand of wire is threaded through the edges of the mesh and picketed down at 3- to 4-foot intervals along its length. A hairpin type of picket (¼- to ½-inch round steel bar, about 30 inches long bent to shape) is desirable. Since the width of chain-link wire mesh normally will be around 6 to 8 feet, it will be necessary to lay at least two sections to obtain a width suitable for traffic, and a minimum 1-foot overlap is required. A disadvantage of chain-link fence is that a single break will cause ravelling to take place.

c. Chicken Wire and Expanded Metal Lath. Chicken wire and expanded metal lath are put down in essentially the same manner as chain-link wire mesh. If chicken wire, 3 feet wide, is used, the roadway should be laid in five widths with 1-foot overlaps and fastened together with plain wire. One layer of chicken wire has been found sufficient for only the lightest of traffic, and at least three layers are required to sustain trucks for even a short time as compared with one layer of heavy chain-link wire mesh. Chicken wire as an expedient road surfacing requires constant maintenance.

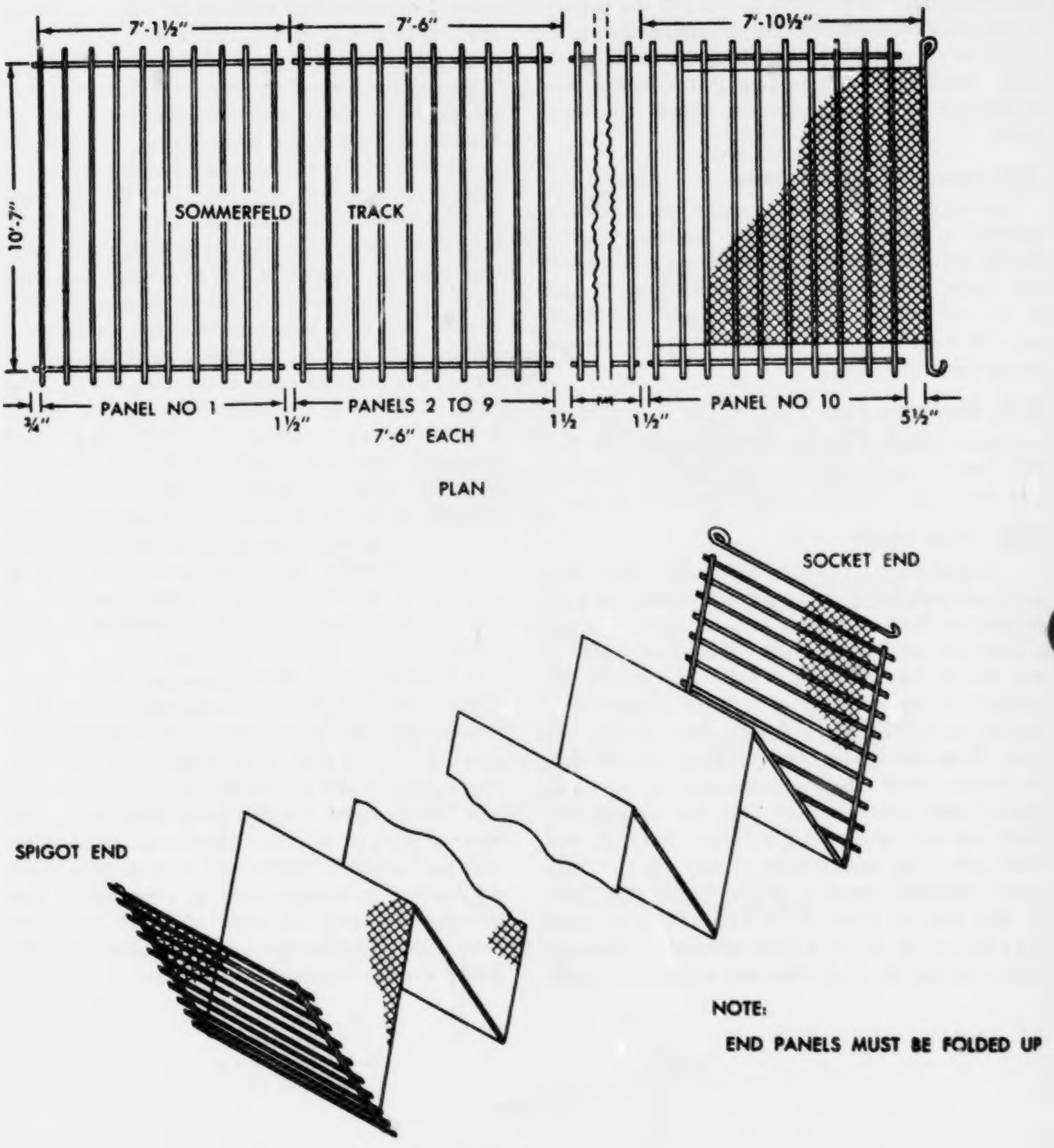

7'-1½"
7'-6"
7'-10½"
10'-7"
SOMMERFELD
TRACK
¾"
PANEL NO 1
1½"
PANELS 2 TO 9
7'-6" EACH
1½
1½"
PANEL NO 10
5½"
PLAN
SOCKET END
SPIGOT END
NOTE:
END PANELS MUST BE FOLDED UP

Figure 144. Method of folding a monkton pack.

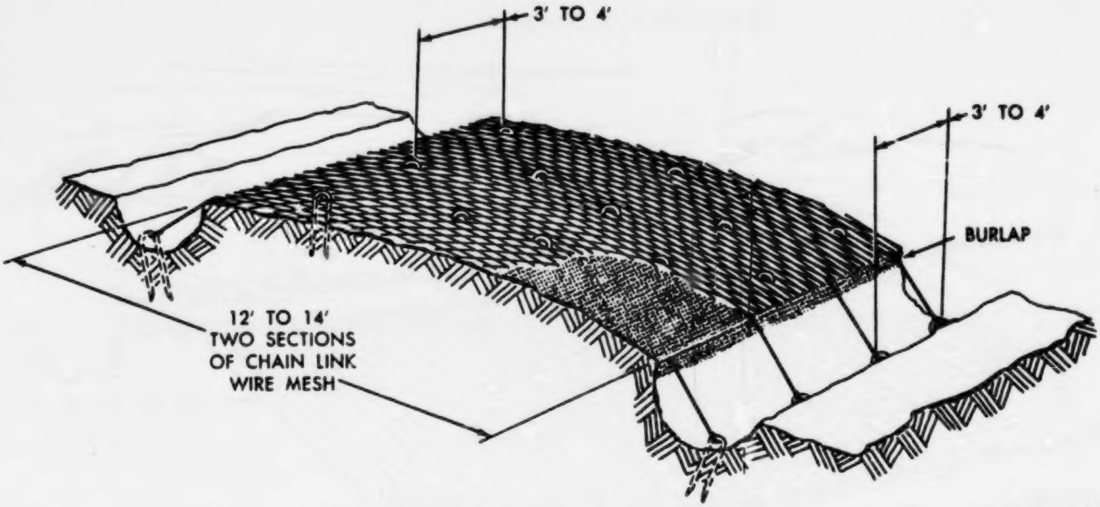


Figure 145. Construction details for a chain-link wire mesh road.

Section III. HEAVY EXPEDIENT ROADS AND PIONEER TRAILS

366. Criteria

The construction of heavy expedient roads follows the same general pattern as that of ordinary roads. Since heavy expedient roads are often used over muddy and swampy ground, it may not be possible to follow usual construction methods completely. However, the usual operations, which should be followed whenever possible, are as follows:

a. Clear road location.

b. Install drainage facilities.

c. Grade the foundation, crowning it from the center or side depending on the type of road to be laid, or giving it a transverse slope, if required.

d. Lay the expedient material, assuring that it has good bearing and is well fastened in place.

e. Construct one-way roads with turnouts every ¼ mile. If two-way traffic is desired, lay single tracks side by side.

f. Maintain the road. Expedient roads need more maintenance than ordinary roads.

g. Replace expedient roads with more durable roads as soon as possible.

367. Mat Roads

a. Use. In general, M6, M8, and M9 mats are used in the same manner for roads as for airfields and the planks laid transversely as shown in figure 146. An exception to this is that the planks are laid longitudinally to form a tread-type road.

b. Initial Layer. Landing mats can be placed directly on the sand to the length and width desired, but burlap or straw underneath the planking greatly improves the flotation. The smoother and firmer the subgrade, the better the resulting road. The mat is placed so that its long axis is perpendicular to the flow of traffic and the panels are locked together. (para 328). If a width greater than the effective length of one plank is constructed, manufactured, or fabricated in the field, half sections are used to facilitate staggering of joints. When landing mat is used over a muddy base, the mud oozes through the perforations and the mat sinks, so that it becomes ineffective. Use of membrane surfacing, brush, or burlap over the base prevents the pumping of the mud, resulting in a more effective expedient surface.

c. Second Layer. A second layer of steel mat, laid as a treadway over the initial layer, will further increase its effectiveness. In either case, the foundations should be as smooth as possible. One layer of mat constitutes a hasty road.

d. Addition layers. A heavy expedient road can be constructed by using several layers of the mat with the panels in each successive layer being laid perpendicular to each other. The tendency of the mat to curl up at the ends can be overcome by making an excavation at the edges of the road about 1 foot deep with a 3 to 1 slope on the side of the excavation nearest the road. The mats are bent

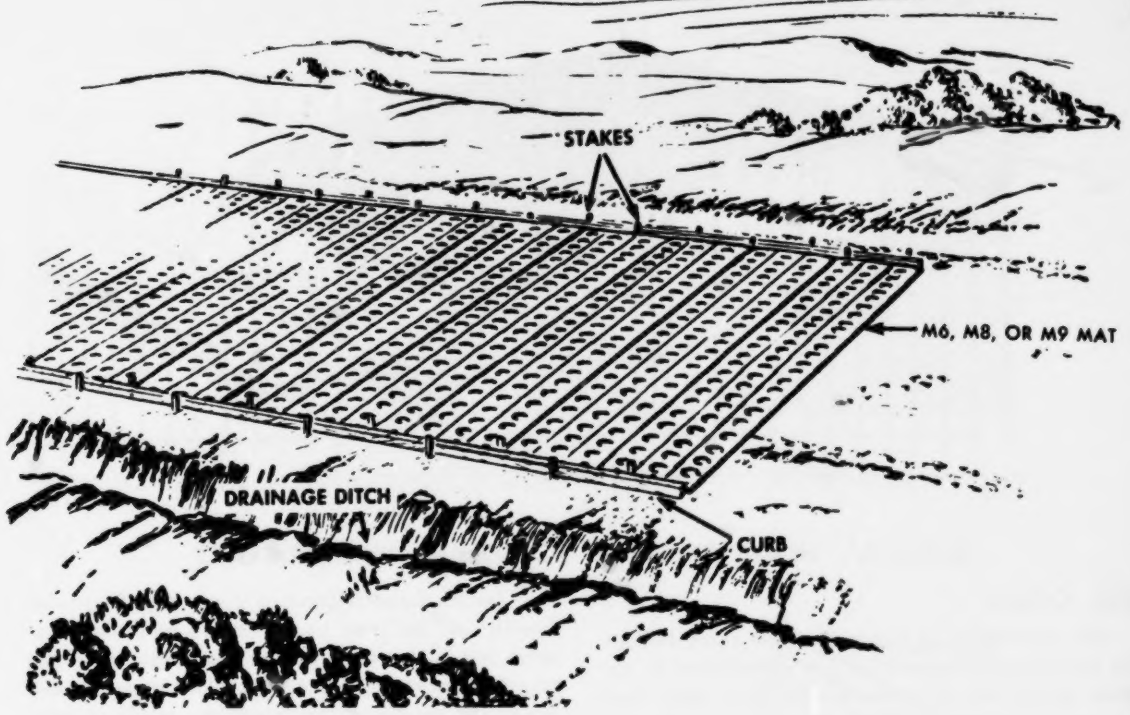


Figure 146. Mat road.

to fit the trench and placed in position, and the excavation is backfilled over them. Another method of securing the edges is to use a curb of logs or finished timber on the outside edge of the road. Also, the edges can be either wired tightly to buried logs laid parallel to the road or staked down.

e. Maintenance. The landing mat requires constant maintenance and may be damaged by tracked vehicles to the point where salvage and reuse are impossible. When the mat is wet, it is very slippery and dangerous to moving vehicles.

368. Plank Roads

Plank roads are used for crossing short sections of loose sand or wet soft ground. When well-built with an adequate base, they last for many months. Planks, 3 to 4 inches thick, 8 to 12 inches wide, and at least 13 feet long, are desirable for flooring, stringers, and sleepers. When desired, 3- by 10-inch planks (rough, not finished) can replace the 4- by 10-inch timbers shown in figure 147; rough, 3- by 8-inch and 3- by 10-inch planks can be cut to order. Stringers are laid in regular rows, parallel to the centerline, on 3-foot centers, and with the joints staggered. Floor planks are laid across the stringers with about 1-inch gaps when seasoned lumber is used, to allow for swell when the lumber absorbs moisture. They are spiked to every stringer. Six-inch-deep guardrails are placed on each side, with a 12-inch gap left between successive lengths of the guardrail for drainage of surface water. Pickets are placed along each side at 15-foot intervals to hold the roadway in line. Where necessary, corduroy, fascine, or other expedient cross sleepers, spaced on 3- to 5-foot centers, are used to hold the stringers in correct position and/or to gain depth for the structure. For drainage, the base for a plank road is constructed with transverse slope instead of a center crown. To produce a smoother riding surface, treads parallel to the line of traffic are often placed over the floor planks.

369. Corduroy Roads

a. Types. Where timber is conveniently available, a corduroy road can be built over soft ground, such as muddy terrain. Corduroy roads

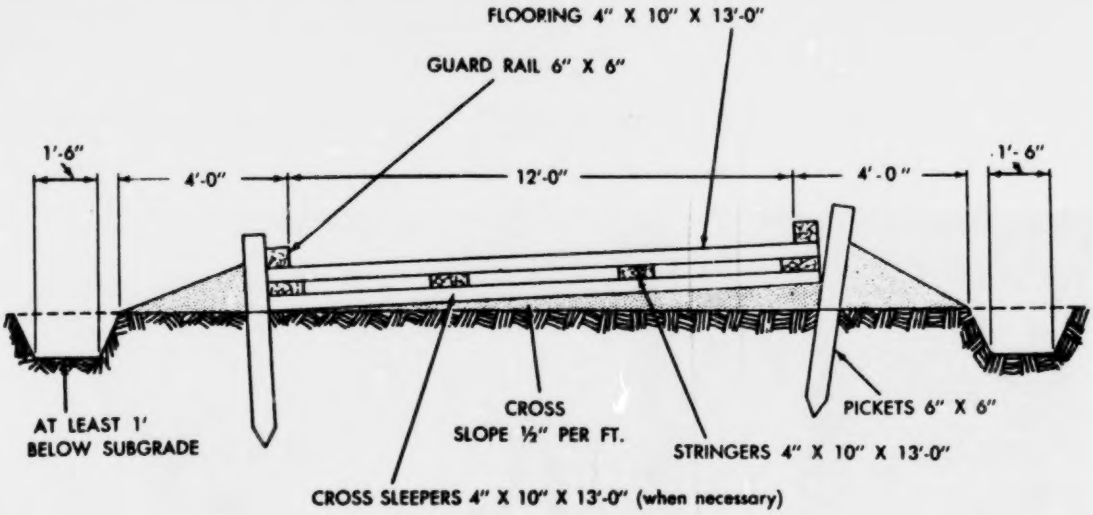

FLOORING 4" X 10" X 13'-0"
GUARD RAIL 6" X 6"
1'-6"
4'-0"
12'-0"
4'-0"
1'-6"
AT LEAST 1' BELOW SUBGRADE
CROSS SLOPE ½" PER FT.
PICKETS 6" X 6"
STRINGERS 4" X 10" X 13'-0"
CROSS SLEEPERS 4" X 10" X 13'-0" (when necessary)

Figure 147. Construction details for plank road.

are made of logs, split or round, laid across the centerline of the road. Corduroy roads are plank roads with native timber substituted for finished or rough lumber. The three general types of corduroy roads are—

(1) Standard corduroy (cross logs laid directly on the ground).

(2) Corduroy with log stringers.

(3) Heavy corduroy (cross logs and stringers laid on sleepers).

b. Construction.

(1) *Standard corduroy.* The most frequently constructed corduroy is the standard type. This involves the placing of 6-inch to 8-inch-diameter logs about 12 feet long adjacent to each other (butt to tip). Along the edges of the roadway thus formed, 6-inch-diameter logs are placed as curbs and wired or drift-pinned in place. Pickets about 4 feet long are driven into the ground at regular intervals along the outside edge of the road to hold the road in place. To give this surface greater smoothness, the chinks between logs should be filled with brush, rubble, or twigs, and the whole surface covered with a layer of gravel or dirt. Side ditches and culverts are constructed as for normal roads. Standard corduroy is illustrated in figures 148 and 149. Corduroy covered with earth is shown in figure 150.

(2) *Corduroy with stringers.* A more substantial corduroy road can be made by placing log stringers parallel to the centerline on about 3-foot centers and then laying the corduroy, as described above, over them. The corduroy decking is securely pinned to the stringers and then the surface is prepared as shown in figure 151.

(3) *Heavy corduroy.* Heavy corduroy involves the use of sleepers, that is, heavy logs, 10- to 12-inches in diameter and long enough to carry the entire road, placed at right angles to the centerline on 4-foot centers. On top of these, corduroy with stringers is constructed (fig. 152). Thus heavy corduroy has three layers, corduroy with stringers has two layers, and plain or standard corduroy consists of only one layer.

c. Selection of Type. The general rule for determining which type of corduroy to use in a given situation is, the softer the ground, the heavier the type of corduroy required. The stringers and sleepers do not increase the bearing capacity of the decking. They serve as a crib, keeping the road surface above the level of the surrounding mud, while sinking into the ground themselves until they reach a stratum capable of supporting the load. In other words, they provide depth for a stable structure. On fairly firm ground the standard corduroy might very well be adequate, on softer ground stringers are needed, and on extremely soft ground

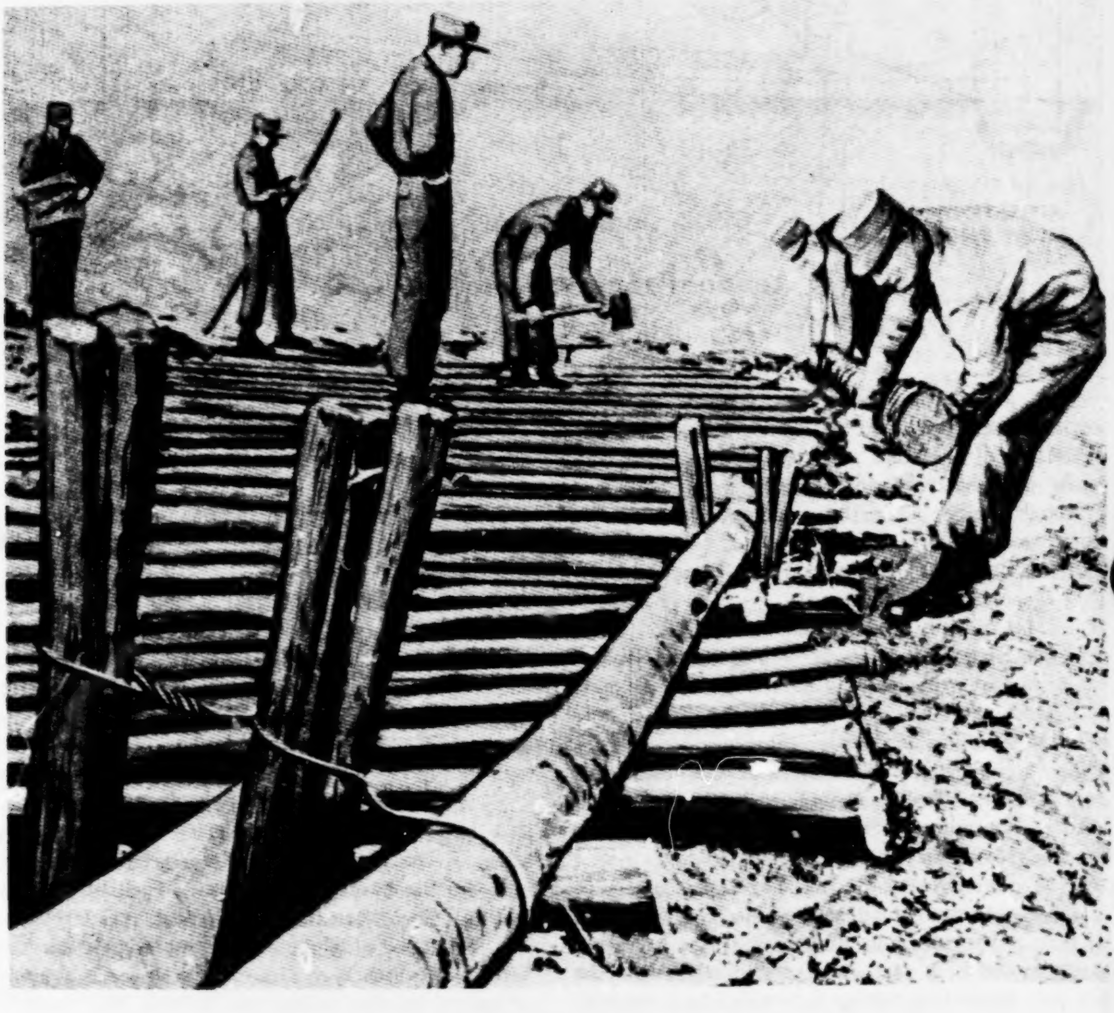


Figure 148. Constructing a corduroy road.

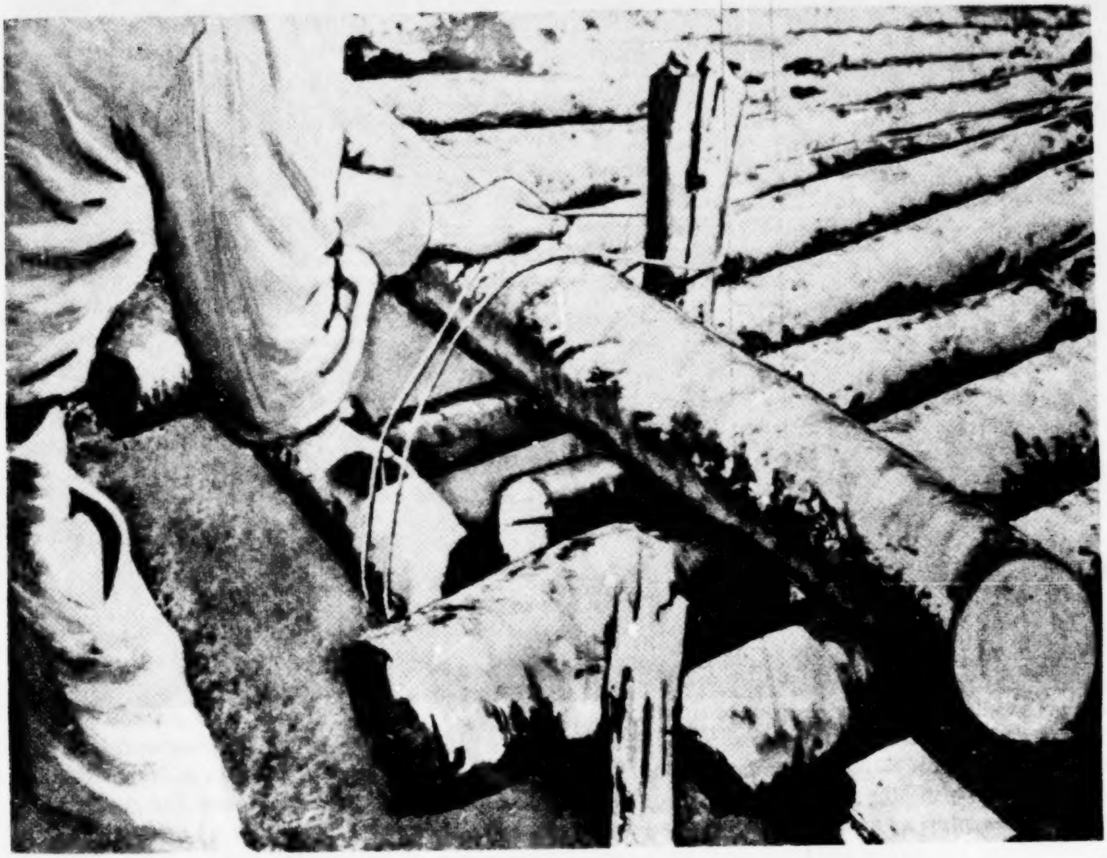


Figure 149. Wiring the guard log on a corduroy road.

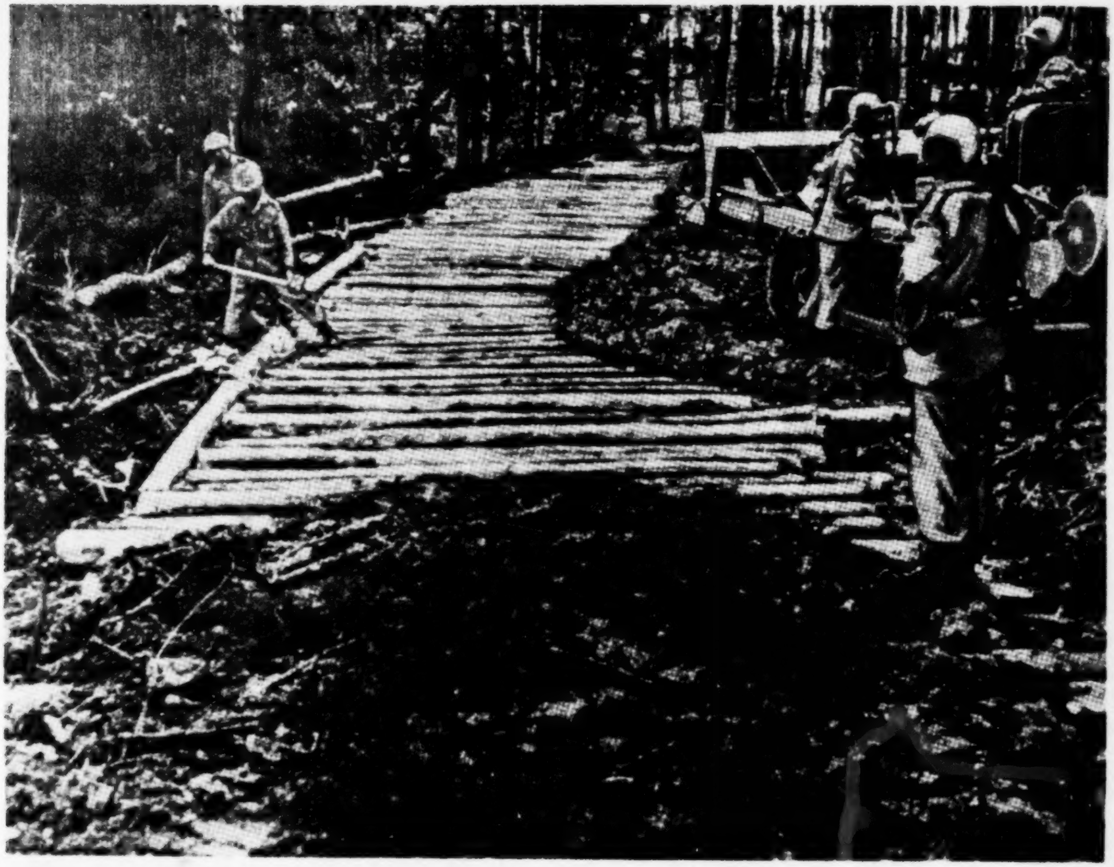


Figure 150. Covering a corduroy road with an earth wearing surface.

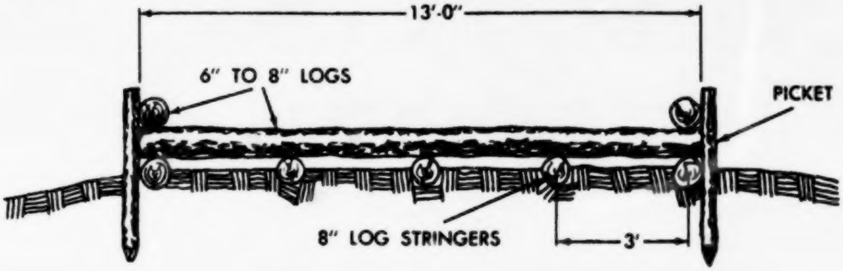

13'-0"
6" TO 8" LOGS
PICKET
8" LOG STRINGERS
3'

Figure 161. Corduroy road with stringers.

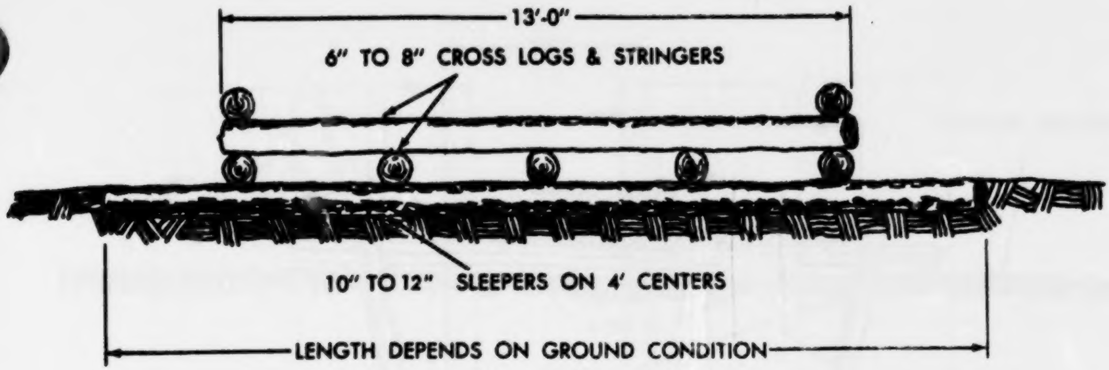

13'-0"
6" TO 8" CROSS LOGS & STRINGERS
10" TO 12" SLEEPERS ON 4' CENTERS
LENGTH DEPENDS ON GROUND CONDITION

Figure 152. Heavy corduroy road.

sleepers also may be required. Portable corduroy mats made by wiring together 4-inch-diameter logs can be prefabricated and put down quickly when needed. (This is very similar to chespaling mat, although heavier.)

d. Diagonal Corduroying. Diagonal corduroying is a modified construction that can be used in any of the types listed in *a* above. The only difference between diagonal and standard corduroying is that the corduroy is placed at an angle of about 45° to the centerline. Diagonal corduroying decreases impact loading on corduroy decking because only one wheel comes in contact with a log at a time. It provides for both longitudinal and lateral road distribution and is preferred for heavy traffic. However, it has a higher maintenance factor and requires logs 50 percent longer than standard types of corduroy construction.

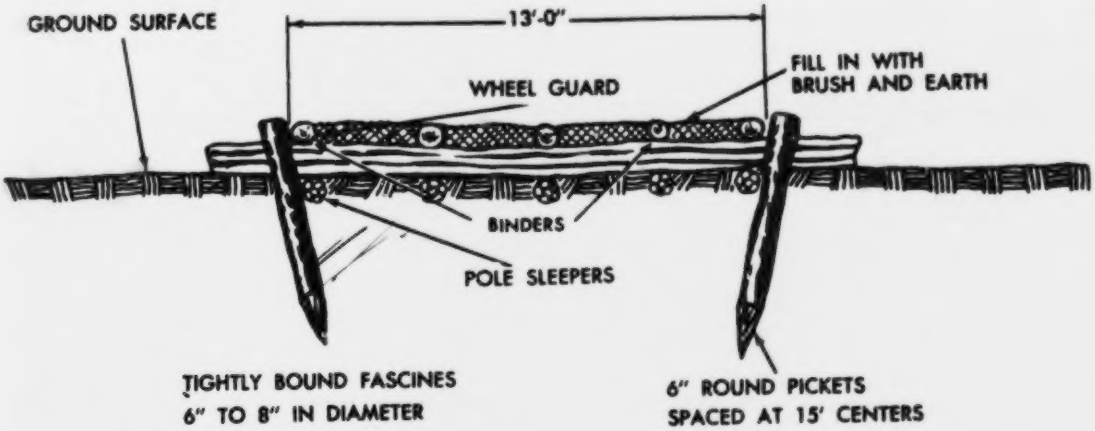
e. Disadvantages. The greatest objection to corduroy roads is the roughness of the surface. Gravel, earth, straw, tall weeds, or fine brush covered with earth can be used for a smoother surface. If suitable materials can be found with which to put a thin covering over the corduroy and if the foundation is stable, a good temporary road can be made. Side ditches and culverts are constructed as for a normal road. If tracked vehicles are to use the road, a blanket of earth or gravel must be provided to protect the road surface.

370. Fascine Corduroy

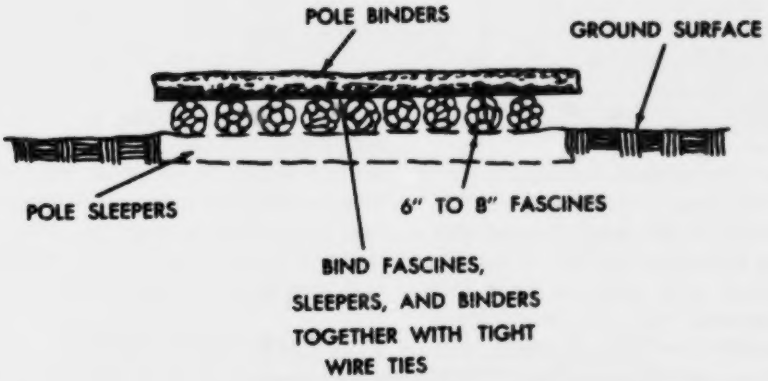
Fascine corduroy roads are suitable expedients in swampy or boggy ground where neither logs nor standing timber are readily available, but where secondary growth, small trees, brush or saplings are available in quantity for binding into bundles. Fascines are built from straight pieces on the outside. The bundle is bound tightly every 18 inches with wire or tarred rope. The fascines are used in much the same manner as logs for corduroy. They are laid crosswise on sleepers of saplings, which are laid parallel to the centerline of the road and on 2- to 4-foot centers. Wire ties are attached to these sleepers at about 2-foot intervals. The fascines are laid as compactly as possible on the sleepers, and the wire ties are pulled up above the surface of the fascines. Longitudinal binders of saplings are then made fast to the fascines and sleepers and squeezed and tied together as tightly as possible. This construction results in a continuous mat of fascines (fig. 153). Brush, sod, reeds, grass or hay, and earth are placed on the fascine mat to form the finished roadway. A fascine corduroy road will carry loads comparable to those carried by a corduroy log road, but it is harder to construct and requires constant attention and maintenance. Wetting down a fascine road from time to time will help the individual pieces of brush to retain their springiness and will keep them from becoming brittle.

371. Plank-Tread Roads

Plank-tread roads can be constructed easily and rapidly and require less material than the ordinary plank roads discussed in paragraph 368. Construction details for a plank-tread road are shown in figure 154. Sleepers of 2- by 10-inch material, 12 to 16 feet long, are laid across the centerline of the road and embedded in the ground on approximately 10- to 16-foot centers. Spacing depends on the length of plank available for tread; however, if the sleepers are thicker than 2 feet and/or hold the flooring too high off the ground, the spacing of the


GROUND SURFACE
13'-0"
FILL IN WITH BRUSH AND EARTH
WHEEL GUARD
BINDERS
POLE SLEEPERS
TIGHTLY BOUND FASCINES 6" TO 8" IN DIAMETER
6" ROUND PICKETS SPACED AT 15' CENTERS

TRANSVERSE SECTION


POLE BINDERS
GROUND SURFACE
POLE SLEEPERS
6" TO 8" FASCINES
BIND FASCINES, SLEEPERS, AND BINDERS TOGETHER WITH TIGHT WIRE TIES

LONGITUDINAL SECTION

Figure 168. Construction details for a fascine corduroy road.

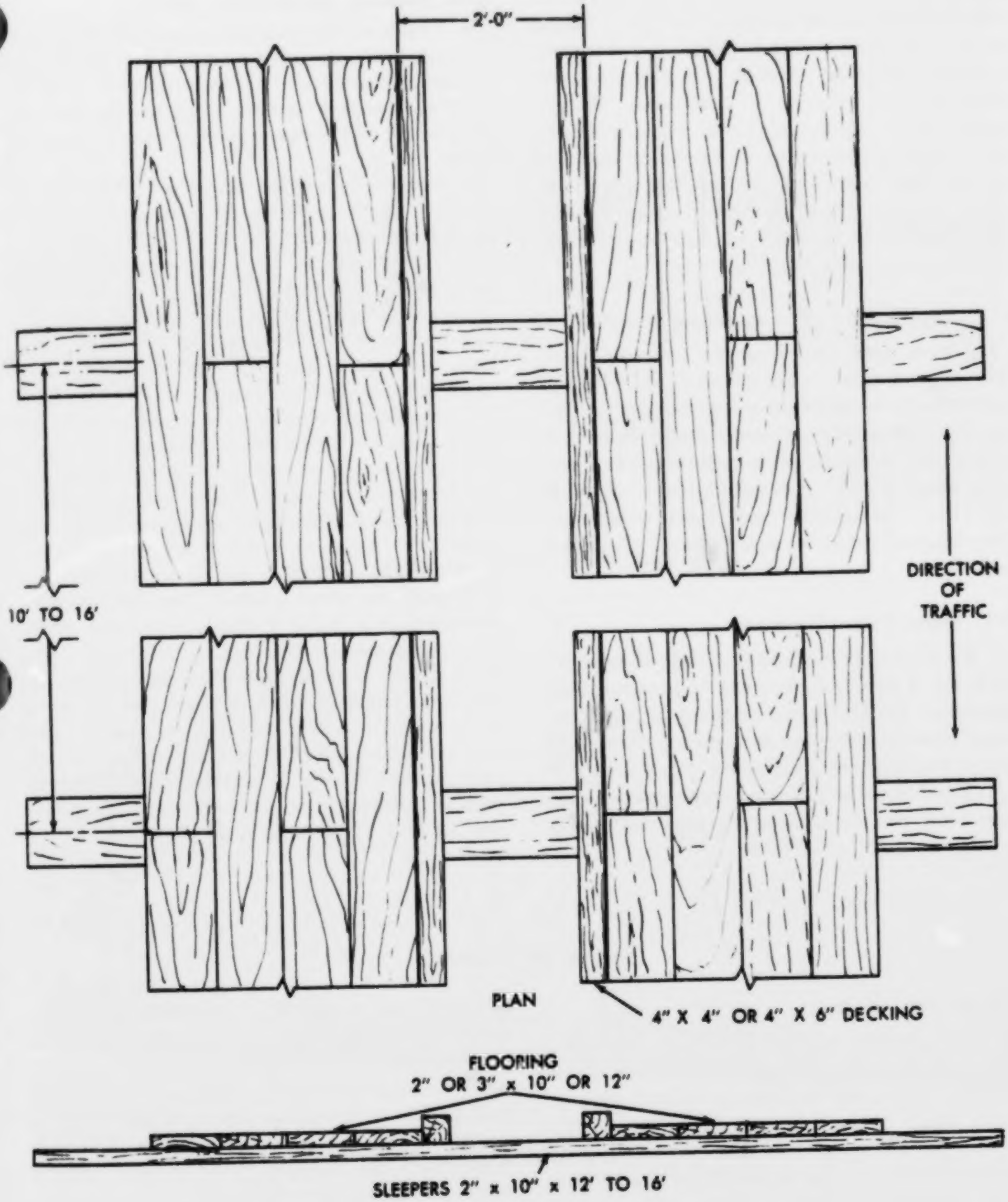

2'-0"
DIRECTION OF TRAFFIC
10' TO 16'
PLAN
4" X 4" OR 4" X 6" DECKING
FLOORING 2" OR 3" x 10" OR 12"
SLEEPERS 2" x 10" x 12' TO 16'
CROSS SECTION

Figure 154. Construction details for plank-tread road.

sleepers must be greatly reduced as the flooring will carry the load without excessive bending. Flooring planks, 2 to 3 inches thick by 10 to 12 inches wide, are laid on top of the crossties. A 2-inch plank will suffice as road surfacing in most cases. For extremely severe conditions, 3-inch plank should be used. Tread sections may be fabricated and laid directly from a truckbed to facilitate placement. Curbs normally are placed on the inside of each tread, sufficiently far apart to allow clearance for the narrowest vehicle to use the road.

372. Log-Plank and Log-Tread Roads

Log-tread roads may be quickly and easily constructed with a minimum of material. The logs must be securely spiked to crossties to prevent the logs from rolling sideways under traffic. Spacing of crossties depends on subgrade conditions, but is generally about 3 feet. Here again, curbs should be used either as in corduroy roads or as in tread roads. A log-tread road with the center filled is a log-plank road.

373. Mats Over Corduroy

If the construction procedure outlined in paragraph 367 is followed, mats can be used as heavy expedients. Double layers or more of plank are placed when they are used as heavy expedients; the lower layer is placed longitudinally and the upper layer transversely to the direction of traffic. Sometimes mats can be successfully used with other methods.

374. Pioneer Roads and Trails

a. The expedient roads which have been discussed are used under circumstances which prevent the use of standard methods of road construction. Pioneer roads use standard methods of construction, but are the simplest and most inexpensive types of ordinary roads.

b. Pioneer roads differ from the higher types of ordinary roads mainly in the matter of location; they are justifiable by primitive conditions and low service requirements. They are characterized by many changes in grades, and high maximum grades are acceptable for short stretches. Vehicles may even have to be winched up short stretches of grade while the grade is improved. The building of roads which will not meet the known needs of service is not contemplated, however. The pioneer standard of construction has limitations on grade and curvature, and consequently on standards of service, just as any other type of road. It does not allow indiscriminate choice of excessive grades or curves. The excessive or unnecessary use of long-sustained low grades will be avoided, as will the unwarranted use of broken and steep grades. The distinguishing characteristic is that of flexibility in location. Probably the pioneer location will be abandoned if and when a more permanent road is constructed, but there is no implication of lack of permanency as far as the roadbed itself is concerned, or that the road will not render adequate service during its life, whether short or long. If possible, even the pioneer road or trail should be selected so that it may be improved by stages rather than abandoned for another route.

Section IV. REPAIR

375. Repair of Mat

a. If a membrane dust palliative is not used under a landing mat or if it is ineffective, enough of the subgrade or base may be blown or blasted away to require repair of the subgrade. M6, M8, and M9 mats are flexible enough that they may be rolled up to one side of the runway to permit work to be done on the subgrade as shown in figures 155 and 156. Methods are under development for repair of MX18 and MX19 mats.

b. For a crater caused by bombing, the result is a large hole with twisted, warped, broken planks, separated and disconnected. The best approach is to try to create a square or rectangular hole in the mat by plank removal and/or cutting with a torch. After the crater is properly filled and compacted in shallow lifts, replacement planks may be placed in the hole of the mat. A careful study will determine when planks can be placed in the normal manner or when welding may be required.

c. Figure 157 shows the condition into which a field can degenerate through constant usage. Although this field is now ready for repair, it does portray the long use that can be expected from portable mats when necessary.

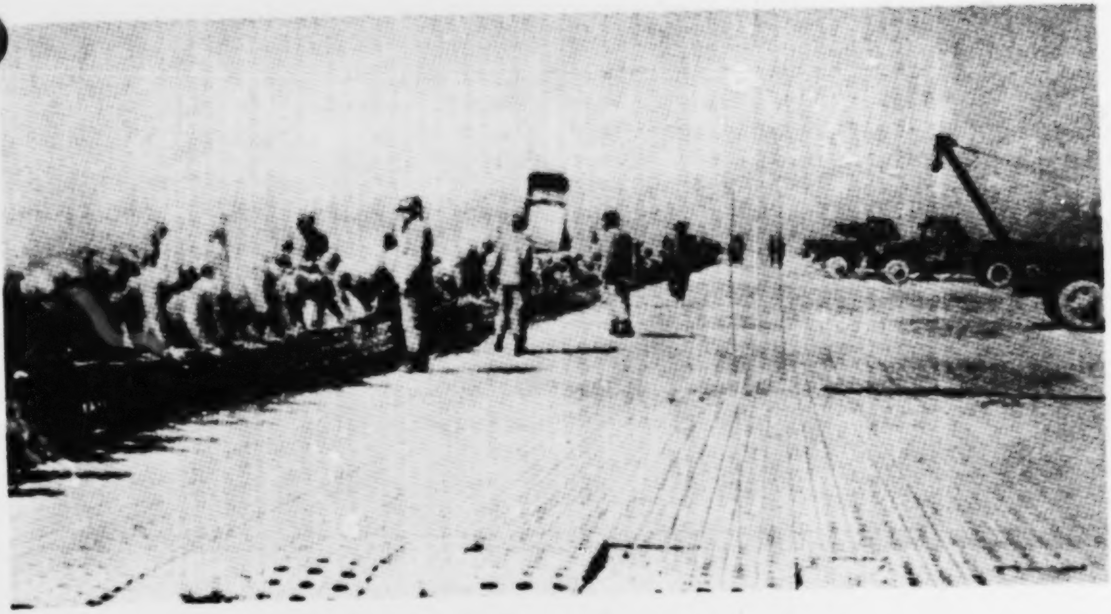


Figure 155. Rolling back M6 mat to repair subgrade.

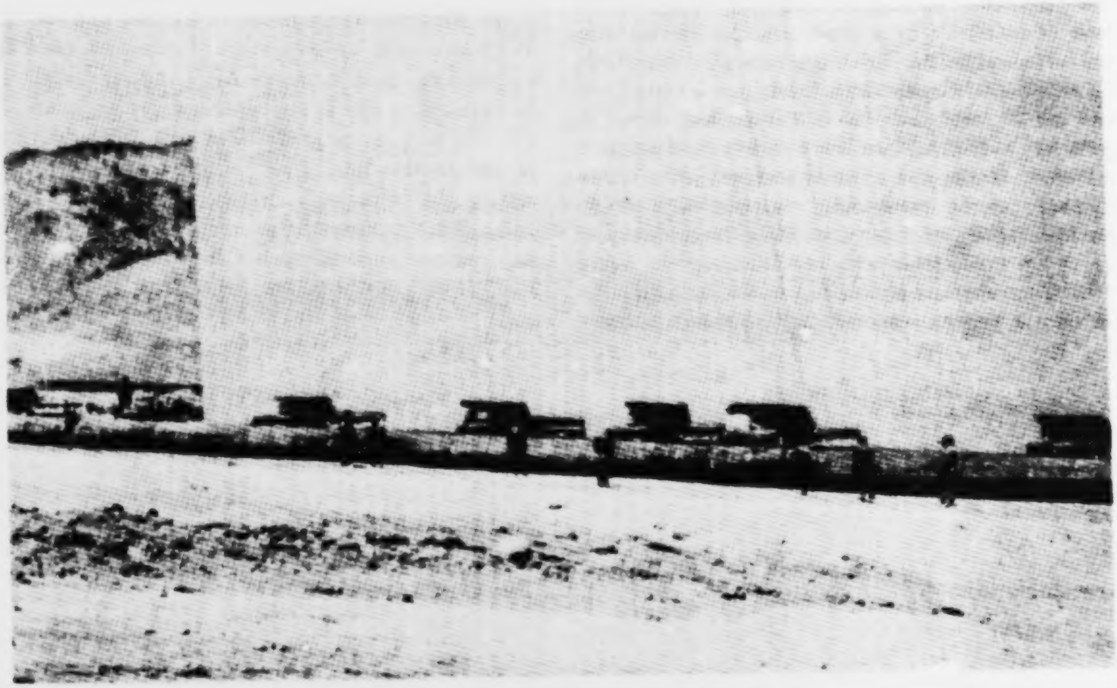


Figure 156. M6 mat rolled back for repair of runway subgrade.

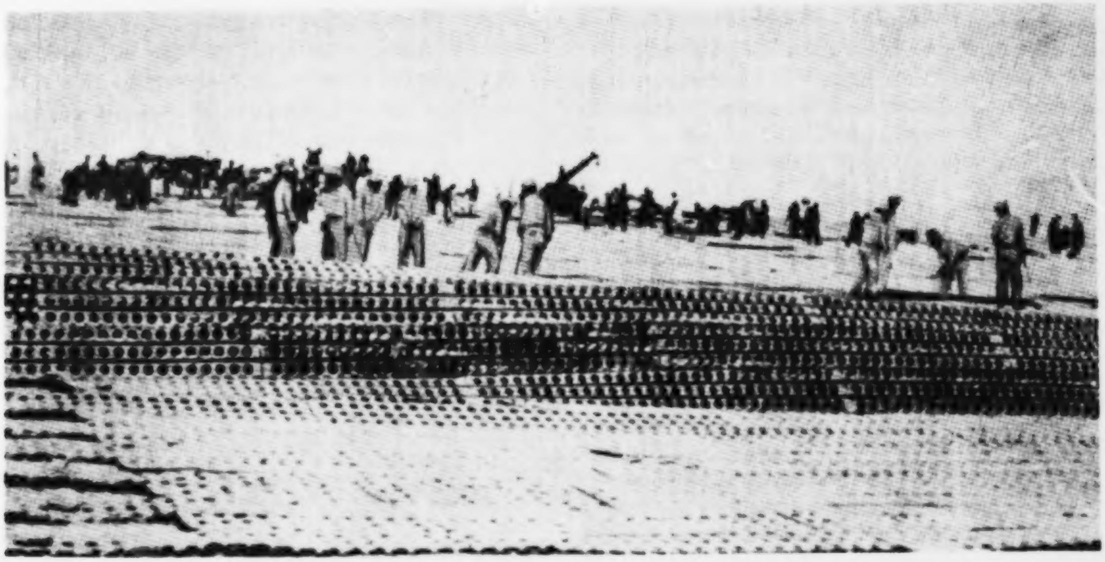


Figure 157. Repair of M6 mat.

376. Surface Repairs With Brick

It is not always possible to repair damaged surfaces to match the original construction, because of lack of materials or a short deadline for opening the surface to traffic. Brick is a very good expedient, because repairs made with brick last a long time and permit immediate use of the surface. Brick is generally available since it is a widely used building material. Roads and airfields with extensive crater damage can be successfully repaired with brick. Surface repairs of craters or other large damaged areas are made with brick as illustrated in figure 158. The subgrade is built up in the same manner as for the original concrete or bituminous surface. A 2- or 3-inch sand cushion is placed on the subbase and graded to a slight crown, to allow for compaction of the sand cushion and settling of the subgrade when the brick patch is finished and rolled. When available, an admixture of cement is used to stabilize the sand cushion. After the sand cushion is prepared, a line is stretched across the center of the hole and set to grade. The first row of bricks is laid to this line. Best results are obtained by setting the brick with stretcher side up and in a herringbone pattern. After completion of the patch, dry cement grout is brushed into the cracks for a seal, and the entire patch is rolled with a 5- to 8-ton roller.

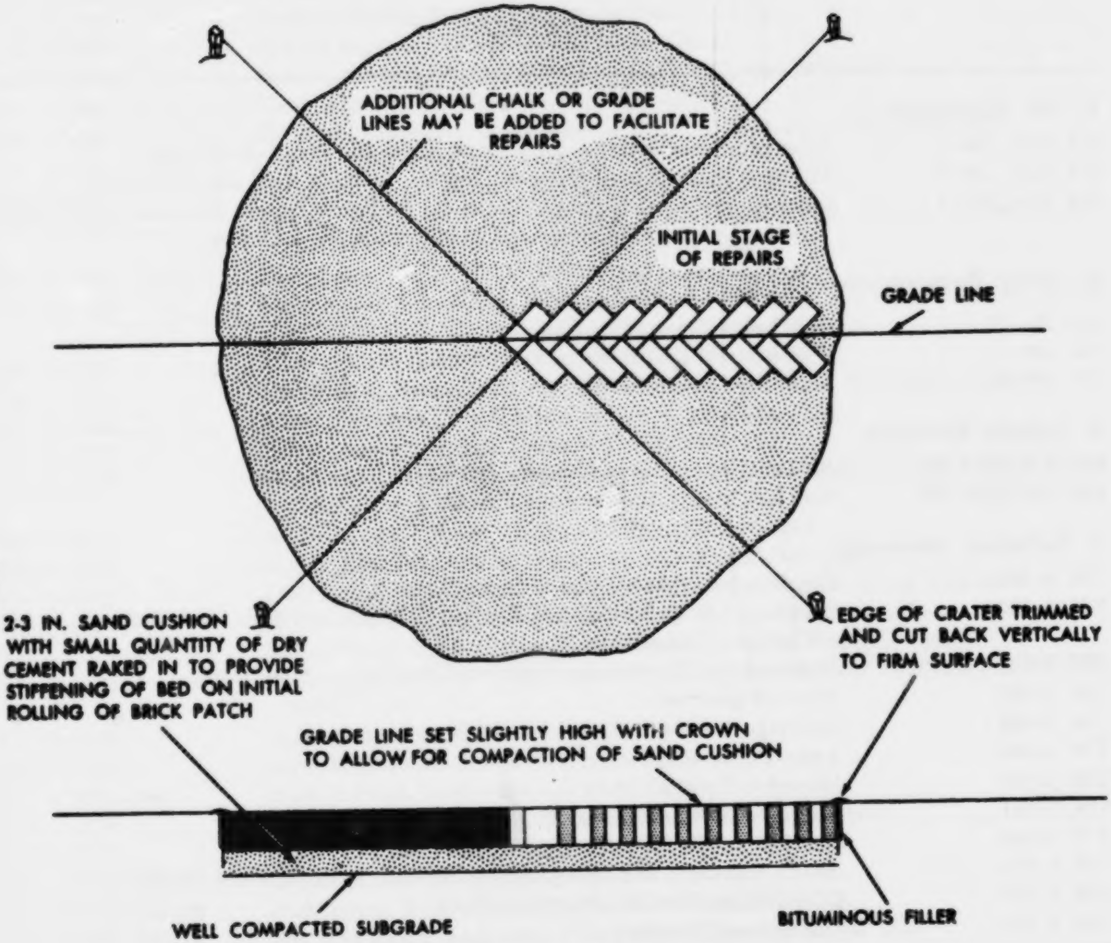

ADDITIONAL CHALK OR GRADE LINES MAY BE ADDED TO FACILITATE REPAIRS
INITIAL STAGE OF REPAIRS
GRADE LINE
2-3 IN. SAND CUSHION WITH SMALL QUANTITY OF DRY CEMENT RAKED IN TO PROVIDE STIFFENING OF BED ON INITIAL ROLLING OF BRICK PATCH
EDGE OF CRATER TRIMMED AND CUT BACK VERTICALLY TO FIRM SURFACE
GRADE LINE SET SLIGHTLY HIGH WITH CROWN TO ALLOW FOR COMPACTION OF SAND CUSHION
WELL COMPACTED SUBGRADE
BITUMINOUS FILLER

Figure 168. Use of brick to surface a crater.

APPENDIX I

REFERENCES

1. DA Pamphlets

DA Pam 108–1	Index of Motion Pictures, Film Strips, Slides and Phono-Recordings
DA Pam 310–5	Military Publications—Index of Graphic Training Aids and Devices.
DA Pam 310–4	Index of Technical Manuals, Technical Bulletins, Supply Manuals, Supply Bulletins, Lubrication Orders, and Modification Work Orders.

2. Army Regulations

AR 220–70	Companies General Provisions
AR 320–5	Dictionary of United States Army Terms
AR 320–50	Authorized Abbreviations

3. Supply Manuals

SM 5–4–3895–S01	Asphalt Mixing and Paving Set: 120 TPH
SM 5–4–5180–S19	Tool Kit, Mason, and Concrete Finisher's

4. Technical Manuals

TM 5–302	Construction in the Theater of Operations
TM 5–330	Planning, Site Selection, and Design of Roads, Airfields, and Heliports in the Theater of Operations.
TM 5–331	Management; Utilization of Engineer Construction Equipment.
TM 5–332	Pits and Quarries
TM 5–335	Drainage Structures, Subgrades and Base Courses.
TM 5–349	Arctic Construction
TM 5–530	Materials Testing
TM 5–541	Control of Soils in Military Construction
TM 5–545	Geology and Its Military Applications
TM 5–624	Roads, Runways, and Miscellaneous Pavements; Repairs and Utilities.
TM 5–704	Construction Print Reading in the Field
TM 5–742	Concrete and Masonry
TM 5–1008	Asphalt Finisher, Barber-Greene Model 879–B
TM 5–1010	Belt Conveyor, Style N, Barber-Greene Co.
TM 5–1011	Dryer, Aggregate, Barber-Greene Model 837, 3895–531–4056.
TM 5–1013	Grader, Road, Motorized, Warco, Model 4D–100.
TM 5–1016	Asphalt Plant (Piping Equip.) Barber-Greene Model, 3895–392–2724.
TM 5–1018	Grader, Road, Caterpillar Model 12
TM 5–1018A	Grader, Road, Caterpillar Model 12
TM 5–1027	Grader, Road, Austin-Western Model 99–H
TM 5–1033	Grader, Road, Galion Model 104 (Less Engine)
TM 5–1039–1	Grader, Road, Caterpillar Model 212
TM 5–1041	Grader, Road, Galion Model 118 (Less Engine)
TM 5–1043	Grader, Road, Rome Model 402

TM 5–1046	Heater, Asphalt, Cleaver-Brooks Model DS–3, 3895–221–1763.
TM 5–1047	Spreader, Sand, Flink Model SS, 3895–250–2419
TM 5–1049	Roller, Road, Galion Model 3–T–9–G, 3895–641–6414.
TM 5–1051	Roller, Road, Grace Model WLTR, 3895–243–2678
TM 5–1057	Roller, Road, Towed Type, Tampo Model R–13, 3895–243–5441
TM 5–1058	Spreader, Concrete, Blaw-Knox Model SA
TM 5–1065	Spreader, Concrete, Blaw-Knox Model SD 3895–243–2734
TM 5–1071	Paver, Concrete, Foote Model 34–E, 3895–221–2764.
TM 5–1078	Heater, Asphalt, Cleaver-Brooks Model DS–31
TM 5–1079	Heater, Asphalt, William Bros. Model SG–45T, 3895–634,9215
TM 5–1081	Tank, Asphalt, Vic Model 72, 2330–294–6302
TM 5–1083	Spreader, Aggregate, Grace Models R and S, 3895–251–7552 (Model S).
TM 5–1092	Grader, Road, Adams Model 124–S
TM 5–1097	Roller, Tandem, Galion Model T5RW, 3895–244–4520.
TM 5–1118	Loader, Aggregate, Barber-Greene Model 82–AM (for Mixer), Model 82–AD (for Dryer), with Buda Engine Model HP–326.
TM 5–1127	Distributor, Water, Butler Model 6743 (Less Engine).
TM 5–1130	Distributor, Bituminous Material, Trailer-Mounted, 1250-Gal. Etnyre Model MX–D4, Style RE, with Le Roi Engine, Model P2877–D2.
TM 5–1131	Mixer, Concrete, Chain Belt Model 16–S, 3895–238–5096.
TM 5–1134	Distributor, Bituminous, Etnyre Model MX–D6 Style RE, 3895–194, 5947.
TM 5–1143	Mixer, Concrete, Gilson Model 16S–SCE, 3895–264–4789.
TM 5–1147	Kettle, Asphalt, Roscoe Model KO, 3895–252–1183.
TM 5–1149	Distributor, Water, Municipal Supply Co. Model WD–1000 (Less Engine) (Less Truck).
TM 5–1157	Kettle, Asphalt, Aerial Model 7–ZPSA, 3895–247–7591.
TM 5–1158	Kettle, Asphalt, Littleford Model 84–HD–3, 3895–247–7593.
TM 5–1161	Distributor, Water, Roscoe Model MOE (Less Engine) (Less Truck).
TM 5–1167	Kettle, Asphalt, Littleford Model US–84–HD–2, 3895–641–6403.
TM 5–1177	Roller, Road, Buffalo-Springfield Model KX–16C2, 3895–223–8398.
TM 5–1183	Roller, Road, Buffalo-Springfield Models VM–31C and VM–32C, 3895–223–8394.
TM 5–1185	Roller, Road, Galion T5G, 3895–221–1632
TM 5–1281–1	Asphalt Plant, Barber-Greene 10–30 TPH
TM 5–1281–2	Asphalt Plant, Barber-Greene 10–30 TPH
TM 5–1376	Feeder, Aggregate, Barber-Greene Model 815, 3895–515–4651.
TM 5–1555	Mixer, Concrete, Smith Model 499, 3895–238–5101.
TM 5–3805–208–10	Grader, Road, Caterpillar Model 12
TM 5–3825–202–10	Distributor, Water, Pryor Models WD–10 and WD–10–2.
TM 5–3895–200–15	Batching Plant, Aggregate, 3-bin, 100 ton, Stanley Model 1000.
TM 5–3895–201–10	Distributor, Bituminous Material, 800-gallon, Entyre Model C8M1.
TM 5–3895–203–15	Spreader, Aggregate, Towed, Entyre Model C8M1.
TM 5–3895–204–10	Distributor, Bituminous Material, Tankless Type, Littleford Model US3C–2–TOD.
TM 5–3895–205–10	Mixer, Concrete, Construction Machinery Model 16–S.
TM 5–3895–207–10	Roller, Motorized 3-Wheel Type, Galion Iron Works Model CRG.
TM 5–3895–208–10	Mixer, Bituminous Material, Barber-Greene Model 848, 80–110 TPH.
TM 5–3895–210–12	Batching Plant, Cement, 75 ton, Boardman Model 581.
TM 5–3895–215–15	Kettle, Heating, Bituminous, 165 Gal.
TM 5–3895–216–10	Finishing Machine, Concrete, Concrete Machinery Model 10–200–250.
TM 5–3895–217–10	Distributor, Bituminous, Tankless, Seaman-Gunnison Model MTD.
TM 5–3895–218–15	Paving Machine, Bituminous, Barber-Greene Model 879–B

TM 5-3895-219-10	Mixer, Concrete, 16 cu. ft., Construction Machinery Model 16SM.
TM 5-3895-220-15	Distribution, Bituminous, 800 gal, Standard Steel Works Model 424-56-CE6 and Seaman-Gunnison Model 424-56-CE61.
TM 5-4061	Tamper, Backfill, Pneumatic, Worthington Model W-8.
TM 5-4062	Tamper, Backfill, Pneumatic, Ingersoll-Rand Model 34.
TM 5-4151	Tamper, Backfill, Pneumatic, Gardner-Denver Model T-23.
TM 5-4152	Vibrator, Concrete, Pneumatic Ingersoll-Rand
TM 5-4153	Tamper, Backfill, Pneumatic, Hardsoeg Model BT-32.
TM 5-9009	Conveyor Belt, Barber-Greene Model 374
TM 5-9036	Semitrailer, Water Tank, Columbian Steel Tank Co.
TM 5-9585	Conveyor, Drag-Type, Barber-Greene Model 689
TM 5-9586	Conveyor, Drag-Type, Barber-Greene Model 681
TM 5-9594	Conveyor, Belt, Haiss Model 487
TM 5-9596	Conveyor, Belt, Ferguson Model
TM 5-9597	Conveyor, Drag-Type, Haiss Model 484 PM
TM 5-9625	Conveyor, Belt, Universal Engineering Model LFAF

APPENDIX II

CONCRETE PAVING CHECKLIST

1. Preparation

A checklist covering the various construction operations should be prepared. Frequent reference will assure the inspector that no important items are overlooked. The following list is for a typical paving project. It undoubtedly varies in some details from the specification requirements and construction procedures on any particular project. Nevertheless, it will serve as an excellent guide in the preparation of a list for any specific project.

2. Subgrade

a. Soft spots should be identified by proof-rolling or by other means.

b. Soft material should be removed, replaced, and the subgrade recompacted to provide firm, uniform support.

3. Subbase

a. Compaction should be an orderly process.

(1) Spread subgrade materials.
(2) Add water as required.
(3) Process to mix water into the subbase until moisture content and gradation are uniform.

b. Width of the subbase should be as shown on plans.

c. The grade should be slightly higher than pavement fine-grade elevation.

d. If soft spots develop in the subbase, material should be removed, replaced, and recompacted to provide uniform pavement support.

4. Forms

a. Form subgrade is made by slight cutting.

b. Forms should be uniformly supported.

c. Forms should be in good condition.

(1) They should be clean and in good repair.
(2) The form base should be perpendicular to the face.
(3) Forms should be true in all directions (check with straightedge).

d. Locks should be securely fastened.

e. Pins should be securely locked in stake pockets.

f. Forms should be true to a smooth line at correct distance from centerline.

5. Fine Grade

a. Fine-grade machine should be cutting rather than filling.

b. Subgrade planer should be cutting rather than filling.

c. During final compaction, moisture should be added as required and the loosened layer recompacted to specified density.

d. Elevation is checked with a scratch templet.

e. Fine-grade material is cleaned out at form to full depth of form. (Observe forms under fine-grade machine for deflection or side movement.)

6. Steel

a. Keyway forms (along longitiudinal joints) should be fastened to roadway forms at correct elevation.

b. Tie bars, or hook bolts, should be correctly and securely placed (single-lane paving).

(1) Adequate baskets should be firmly and uniformly supported. Small stones used as supports are unsatisfactory.
(2) Baskets should be securely staked to prevent movement.
(3) Expansion joint filler should be perpendicular to subgrade and at proper elevation.
(4) Expansion joint filler should be perpendicular to form line and in true line across pavement.
(5) Dowels of proper dimensions and spacing are placed parallel to the centerline and top of the form line.
(6) Dowels are greased on one side of joint. Usually dowels are coated by the fabricator and alternate dowels are coated on the opposite side of the joint. Generally,

the shop coating indicates the unwelded end of the dowel. A uniform thin coating of grease or graphite mixture must be applied to the free half of each dowel.

(7) Grease on dowels should cover the bottom of the dowel. If brushes are used to paint the dowels, the bottom is frequently missed.

(8) Expansion caps must be placed on the greased ends of dowels in expansion joints.

c. Mesh or bar mat reinforcement is distributed, ready for use, adjacent to the paving area and far enough to the side that workmen do not walk on it.

d. Tie bars must be of proper dimensions and placed at proper spacing.

7. Final Preparation for Concrete

a. Forms are thoroughly oiled.

b. Subbase material should be thoroughly saturated. Intermitten sprinkling may be required throughout the day for several hundred feet ahead of the paver.

c. Final check is made of surface compaction and elevation of fine grade. A light subgrade tester may be kept immediately ahead of concrete operations to check elevation.

d. Final check of forms for line and surface should be made.

e. Batches are dumped into skip. No materials should be lost on the subgrade and none should stick in the truck.

8. Placing Concrete

a. Minimum drop from bucket should be maintained. The bucket should just clear the form when moving out on the boom.

b. Concrete is dumped evenly over the subgrade.

c. Concrete should have a satisfactory appearance.

(1) It should be stiff enough to stand without flowing but easily workable without segregation.

(2) All aggregate particles should be covered with paste and sufficient mortar to fill voids in the coarse aggregate.

(3) There should be no free water at edges of the pile.

d. Spreading should be even—one pass for each course.

e. Strike-off should be uniform at proper elevation for mesh (when used) and high enough to leave a proper amount for finishing.

f. The concrete is vibrated or spaded along forms and at joints. Excessive vibration is indicated when excessive mortar shows or splashes.

g. Mesh is placed correctly without tamping.

h. Tie bars should be properly placed if they are impressed in the concrete or laid on the surface that is struck-off for welded wire fabric.

9. Finishing

a. Concrete in front of screeds should be rolling, not sliding. If it is not rolling, check air entrainment and slump.

b. First screed on first pass should carry a uniform roll of concrete 6 to 8 inches in diameter and leave the concrete surface slightly high.

c. The second screed on the first pass should carry a uniform roll of concrete 2 to 3 inches in diameter and cut the concrete to slightly above the top of the form with a small allowance for initial settlement.

d. Screeds should be lifted at joints when dowels are used.

e. The surface after the transverse finishing machine passes should be smooth and tight with ripple marks. Two passes may be required at times. Tearing can usually be eliminated by increasing the speed of transverse motion in relation to the forward speed.

f. The forward screed should be tilted slightly to provide compaction and surge. Stiff mixes require somewhat greater tilt than mixer with more slump. The rear screed should never be tilted. If the finishing machine is to back up for an additional pass, the forward motion should be continued while the screed is raised. Thus, concrete in front of the screeds is spread rather than left standing in a pile.

g. Removable strips for forming a dummy groove should be placed ahead of the longitudinal finishing machine in a true line and perpendicular to the forms.

h. The longitudinal finishing machine should be held back as far as possible and still permit finishing operations to be completed while the concrete is still plastic.

i. The bull float should carry a small roll of concrete ($\frac{1}{2}$ to 1 inch in diameter) at its forward end. The roll should taper to nothing about 18 inches from the rear end.

j. The bull float must not cut the concrete. If it does, check on the transverse finishing machine and form surfacing and stability. (This assumes that the longitudinal finishing machine is properly adjusted.)

k. The surface after bull floating should be tight, smooth, at final elevation, and have only a faint diagonal marking. If a formed centerline joint is used in full-width paving, it is cut and strips are placed from a centerline machine immediately after the bull float.

l. Hand-operated 12-foot straightedges remove faint diagonal markings; accumulated fine material and water should be removed by pulling the straightedges from center to forms.

m. Straightedges should correct minor discrepancies in elevation. If much of this work is continuously required, the equipment ahead or the forms, or both, are out of adjustment.

n. Surface men close up small holes in the surface. Use of short smoothing lutes or floats should not be permitted as a constant part of finishing operations.

o. The pavement surface should have not more than about ⅛ inch of mortar over the coarse aggregate nearest the surface. No water should be sprinkled on the surface during finishing operations.

p. Longitudinal joints along the forms should be edged to the proper radius.

q. Burlap drag, or other texture, is applied when the surface is barely stiff enough to hold the texture. The burlap should be wet, clean, and not frayed. It should be dragged evenly so that texture marks are uniform and parallel to the centerline.

r. When the burlap drag is not in use, it should be raised from the concrete.

10. Joints

a. *Sawed Joints.*

(1) The location of joints should be marked in such a manner that the marking will not be lost; for example, with a pin or stake beside the form and a stringline snapped across the fresh concrete.

(2) If impressed material to be sawed out is used (paper, plastic, asphalt, or cork board), it is placed following the longitudinal float and positioned to be square and straight across the pavement and perpendicular to the surface.

(3) If a vibrating bar (to move large aggregate from the line of the saw cut) is used following the longitudinal float, it is inserted in the concrete to the depth of the saw cut and withdrawn before overvibration occurs in the concrete.

(4) Sawing should be done before the concrete cracks but late enough that raveling is within allowable tolerances.

(5) Saw cut should be straight and perpendicular to the edge of the pavement.

(6) Depth of the saw cut must be checked.

(7) The saw cut must go through the pavement edge at full depth.

(8) The saw cut must remove impressed material, if used.

(9) A curing cover is placed immediately.

(10) With membrane cutting, the cut should be filled with rope or other removable material, not with sand or similar loose material.

b. *Formed Joints.* Following straightedging or earlier, depending on conditions, joints are cut open along the forming strip (or small cap), the strip raised to the pavement surface and trued with a stringline, and the plastic concrete floated against the strip.

(1) Joint strips are raised after the burlap drag. Care must be taken not to disturb the concrete. (Caps over plates are removed.)

(2) Joint strips (or joint plates) may be used as edging guides.

(3) Joints are edged and finished when the concrete is stiff enough to hold a vertical face but before it is so stiff that mortar must be added to fill irregularities during edging. No concrete can be permitted over a joint plate.

(4) The joint slot must be cut clean and through to the forms.

(5) The surface across joints is checked with a straightedge at least 4 feet long.

(6) The surface texture is brought to the edge of joints.

(7) Loose mortar is cleaned from the joints.

(8) When formed centerline joints are used, joint men remove the plates and do their edging as they finish the transverse joints. If impressed premolded or ribbon joint fillers are used, it is necessary to see that no mortar remains over the joint material.

11. Final Surface Check and Finish

a. After joints are completed, a second burlap drag may be used over the entire pavement.

b. The entire surface is checked with a light 10-foot straightedge.

12. Curing

a. The curing process should be started as soon as possible without marring the surface of the concrete.

b. Burlap should be clean and wet when placed and wet again after placement.

c. Paper rolls should be supported above the soft pavement while they are being unrolled.

d. When paper or polyethylene sheets are used for curing, it may be necessary to apply a mist spray of water immediately ahead of the material if it is placed on hot, dry, windy days.

e. When wet burlap is used for curing, it must not be allowed to dry out but must be kept wet for the specified period.

f. On hot days, it may be necessary to place the curing before joint finishing is complete. It should be placed over the joint. Short sections may be uncovered to finish the joints.

g. The pavement should have a wet surface when final curing is placed after initial burlap curing.

h. Membrane curing compounds should be agitated in the container during application. The amount and uniformity of coverage should be checked for compliance with specifications.

i. All types of curing material should uniformly cover the top and sides of the slab and have at least the specified thickness.

13. Form Removal and Care of Pavement

a. Forms must be removed in such a manner that they will not be twisted or bent. The pavement edges should be protected from damage.

b. Any honeycombing on the side of the slab should be filled immediately with mortar. If much honeycombing is evident, it indicates incorrect vibration or spading during placement of the concrete or it can indicate an incorrect mix.

c. Curing should be brought down over the side of the pavement.

d. Curing should be carefully maintained during the full required period.

e. Curing material should be removed carefully, inspected, and prepared for reuse. Damaged paper or polyethylene curing material should be removed from the job.

f. Sawing of centerline joints should be done after removal of the curing material.

g. All joints are thoroughly cleaned and sealed as soon as possible after the curing period and before construction traffic or other traffic uses the pavement.

h. Joints must be clean and dry when sealing material is placed.

i. Sealing material should fill the joint completely but not overflow or extend onto the pavement.

j. Temporary or permanent shoulder material should be placed adjacent to the slab before any traffic uses the pavement.

14. Dividing the Work

a. One man can inspect all work ahead of the mixer, including placement of the tie bars and joint assemblies.

b. A second man can inspect the condition and alinement of the forms, the correctness of tie bar and joint assemblies immediately ahead of concreting, plus all work from there back to and including the joint crew. This man would generally be responsible for the entire paving operation.

c. A third man can inspect all work beginning with the curing crew and including the rest of the operation.

15. Equipment Inspection

a. All equipment should be maintained in good working order. Frequent breakdowns are reason for shutdowns until the equipment is repaired and ready for use.

b. The subgrader and fine-grade planer should be checked and adjusted as often as required to produce a true fine grade with a minimum of hand work.

c. The subgrade template or scratch board should be adjusted accurately to true fine-grade cross section and should be checked every morning.

d. The mixer should be timed and a locking device in working order should be arranged to control the mixing time. This should be checked several times daily. The number of drum revolutions per minute should be checked at least daily. Water discharge and air-entraining admixture discharge must be calibrated daily for leakage. Air-entraining admixture dispenser and discharge line must be checked frequently for clogging.

e. All spreading, strike-off, and finishing equipment should be examined for excessive wear and accurately set and adjusted before work begins. The manufacturer's recommendations should be followed. Screeds on the finishing machine should be checked daily for proper crown. It must be remembered that final surface quality results from the cumulative effects of all the finishing equipment. All pieces must therefore be adjusted to one another. If considerable care is exercised originally in adjusting the longitudinal float accurately to line and grade, the performance of this machine can be used as a reference for final adjustment of the strike-off and finishing screeds.

16. Control Tests

a. Slump tests should be made at least three times daily and additional tests made as often as needed to maintain uniform consistency.

b. Air-entrainment tests should be made at least three times daily with a minimum of three readings per test. Additional tests should be made when visual inspection indicates a change in the amount of air entrainment.

c. Unit-weight and yield tests should be made in connection with air-entrainment tests at least once per day with additional tests as often as the amount of air entrainment changes.

d. Test beams and cylinders should be cast as required by the specifications. Beams and cylinders should be made by inspectors using approved procedures and not be laborers. Curing of specimens should start promptly and be carefully continued as required. Specimens should be molded at a location where they will not be disturbed until after final set and should be handled carefully at all times. Particular care is required to insure that no beam faces dry out and that the beams are fully supported during the early period of aging.

APPENDIX III

CONVERSION TABLES

Metric to English			English to Metric		
Multiply	**By**	**To obtain**	**Multiply**	**By**	**To obtain**
LENGTH					
centimeters	0.0394	inches	inches	2.54	centimeters
meters	3.28	feet	feet	0.305	meters
meters	1.094	yards	yards	0.914	meters
kilometer	0.621	miles (stat.)	miles (stat.)	1.609	kilometers
kilometer	0.540	miles (naut.)	miles (naut.)	1.853	kilometers
AREA					
sq. centimeters	0.1550	sq. inches	sq. inches	6.45	sq. centimeters
sq. meters	10.76	sq. feet	sq. feet	0.0929	sq. meters
sq. meters	1.196	sq. yards	sq. yards	0.836	sq. meters
VOLUME					
cu. centimeters	0.0610	cu. inches	cu. inches	16.39	cu. centimeters
cu. meters	35.3	cu. feet	cu. feet	0.0283	cu. meters
cu. meters	1.308	cu. yards	cu. yards	0.765	cu. meters
milliliters	0.0338	U.S. liq. ounces	U.S. liq. ounces	29.6	milliliters
liters	1.057	U.S. liq. quarts	U.S. liq. quarts	0.946	liters
liters	0.264	U.S. liq. gallons	U.S. liq. gallons	3.79	liters
WEIGHT					
grams	0.0353	ounces	ounces	28.4	grams
kilograms	2.20	pounds	pounds	0.454	kilograms
metric tons	1.102	short tons	short tons	0.907	metric tons
metric tons	0.984	long tons	long tons	1.016	metric tons

APPENDIX IV

GRADATION SPECIFICATION CURVES FOR BITUMINOUS MIXTURE AGGREGATES

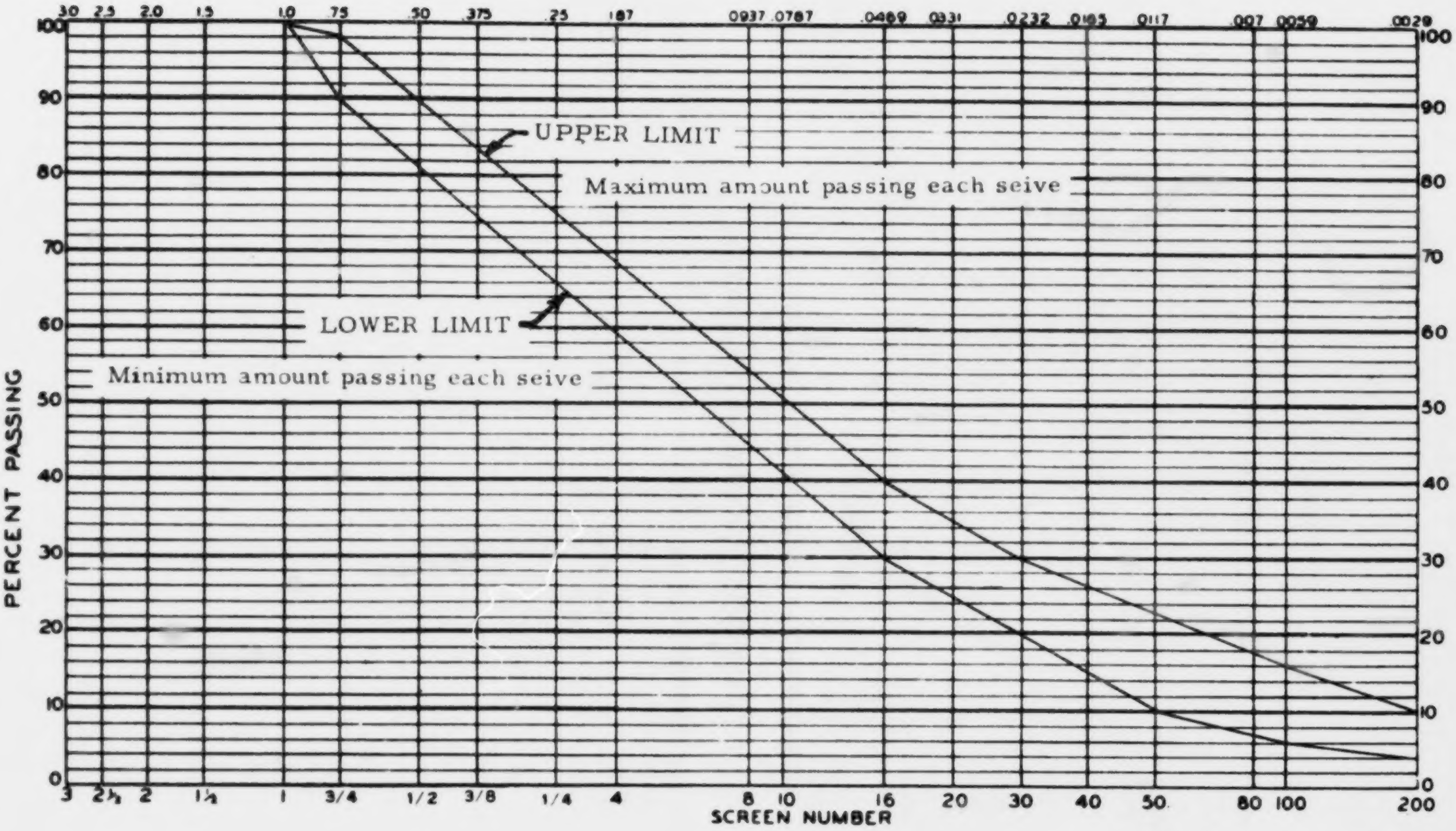


Figure 159. Gradation limits.

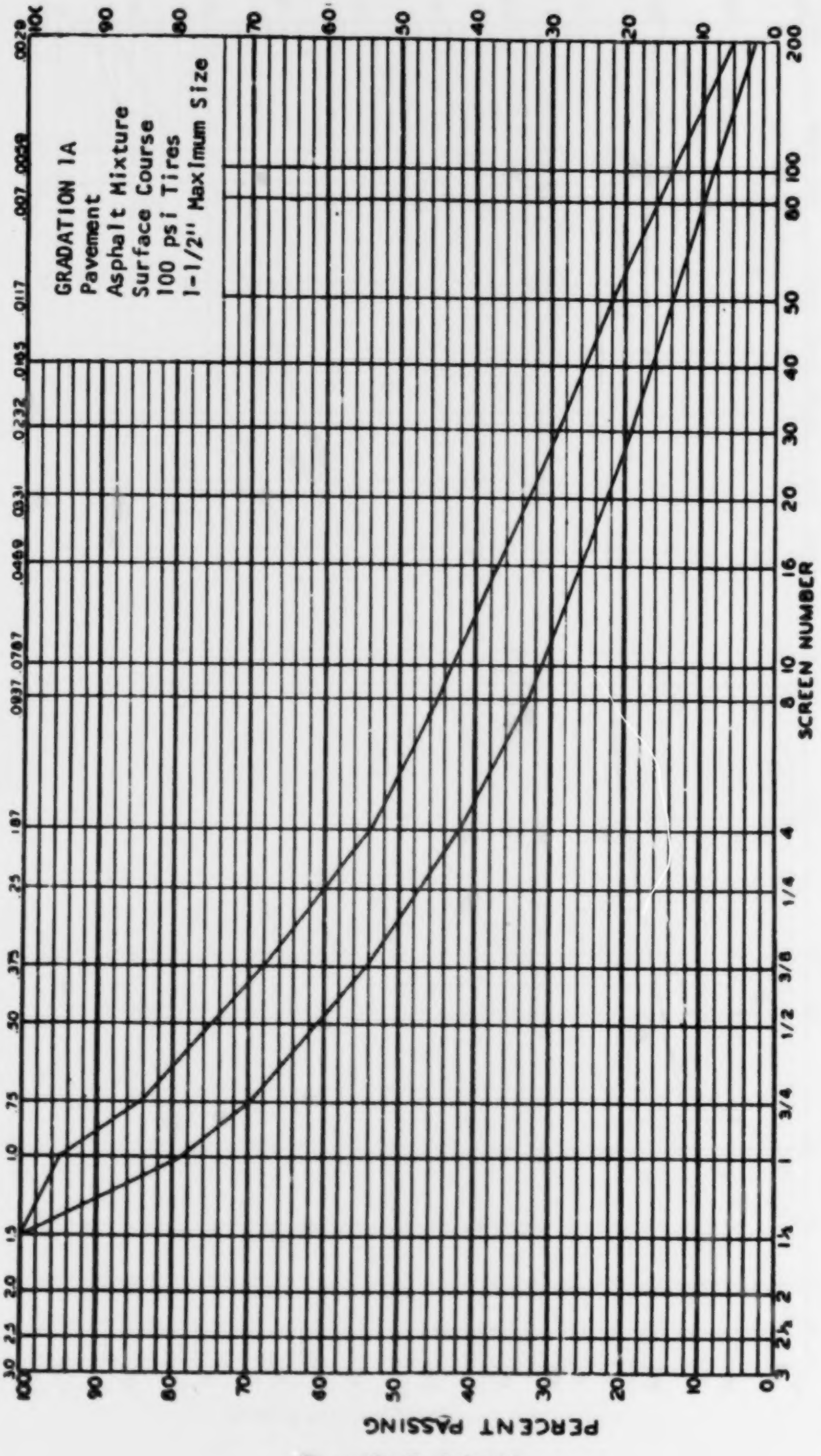


Figure 160. Gradation 1A.

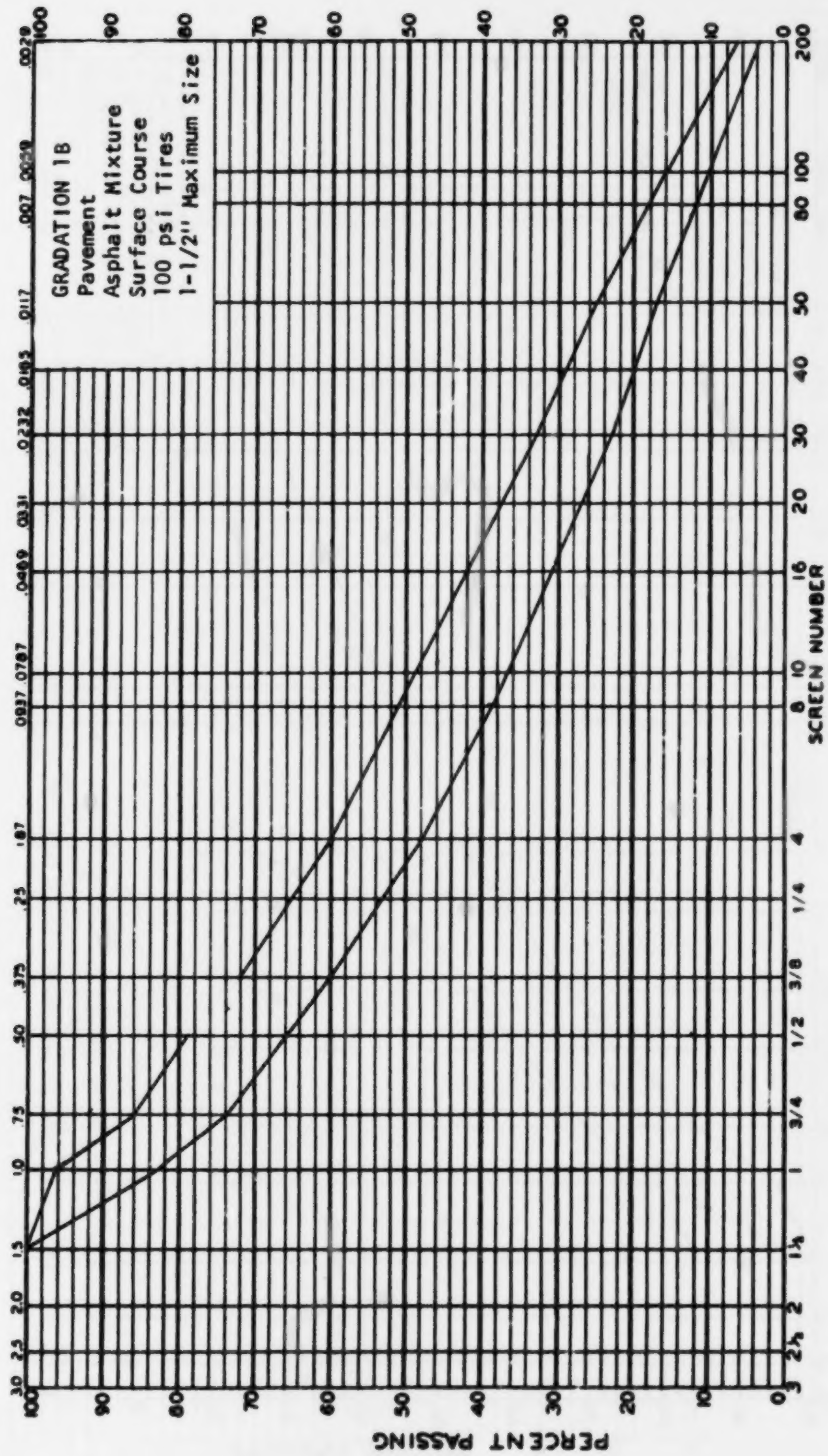


Figure 161. Gradation 1B.

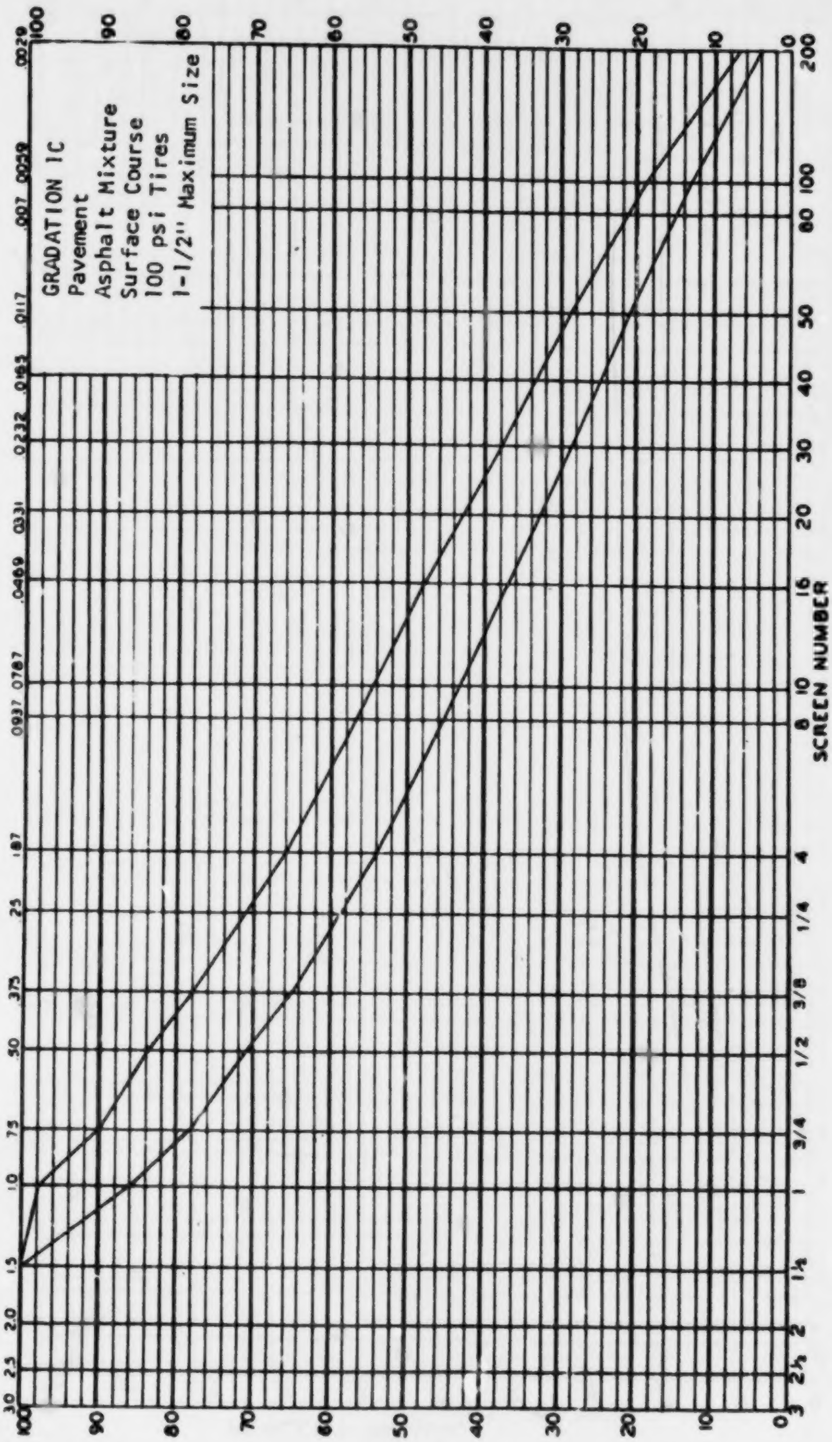


Figure 162. Gradation 1C.

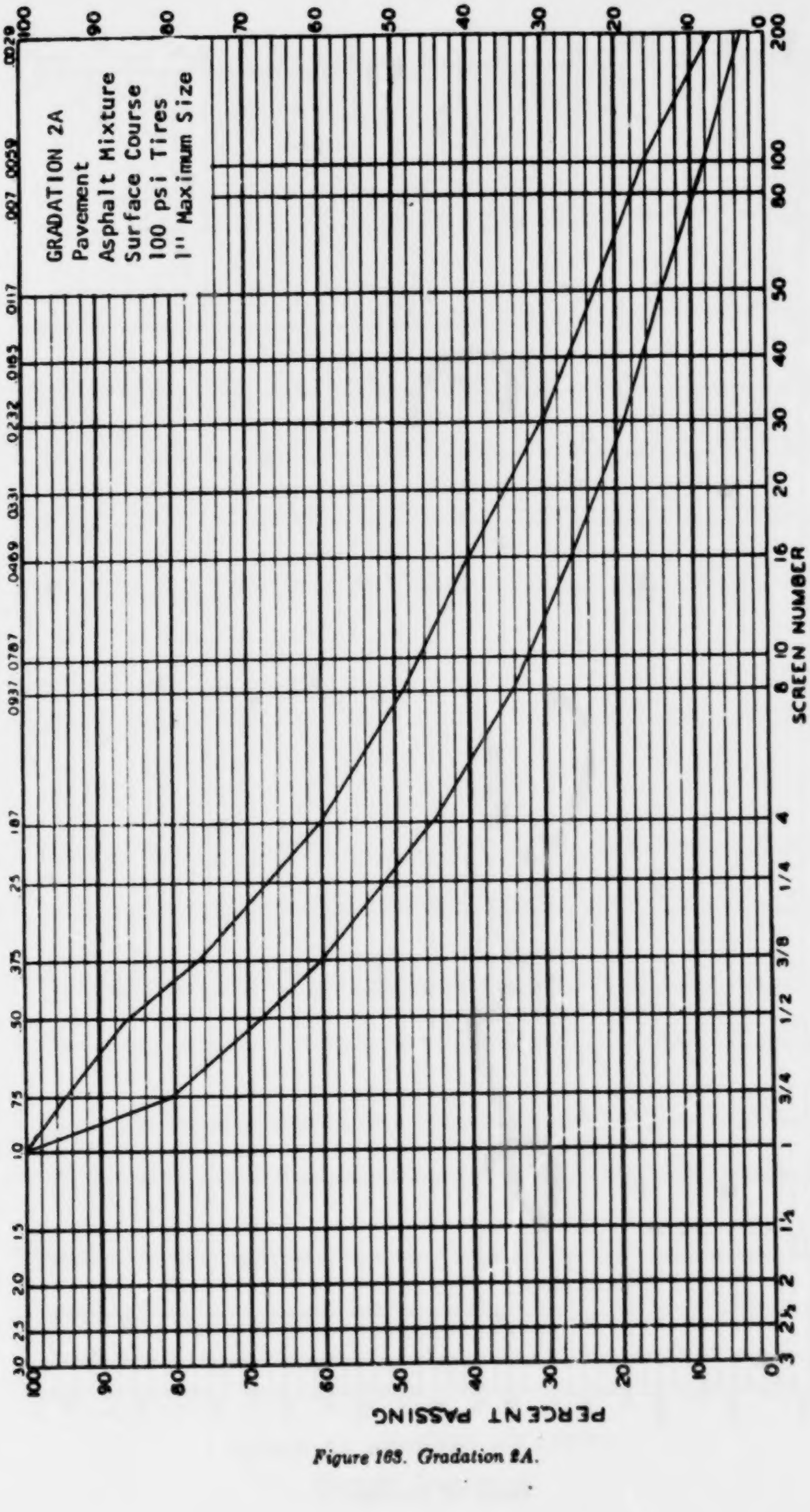


Figure 163. Gradation 2A.

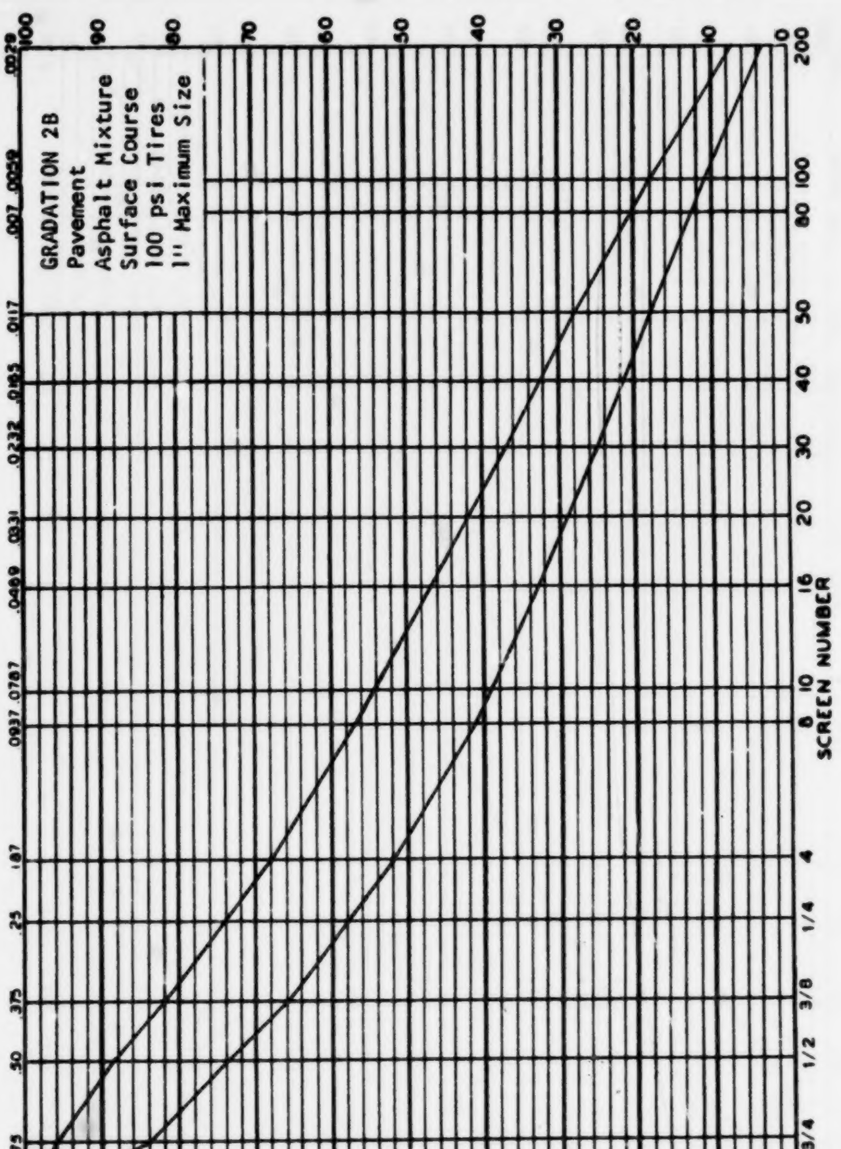


Figure 164. Gradation 2B.

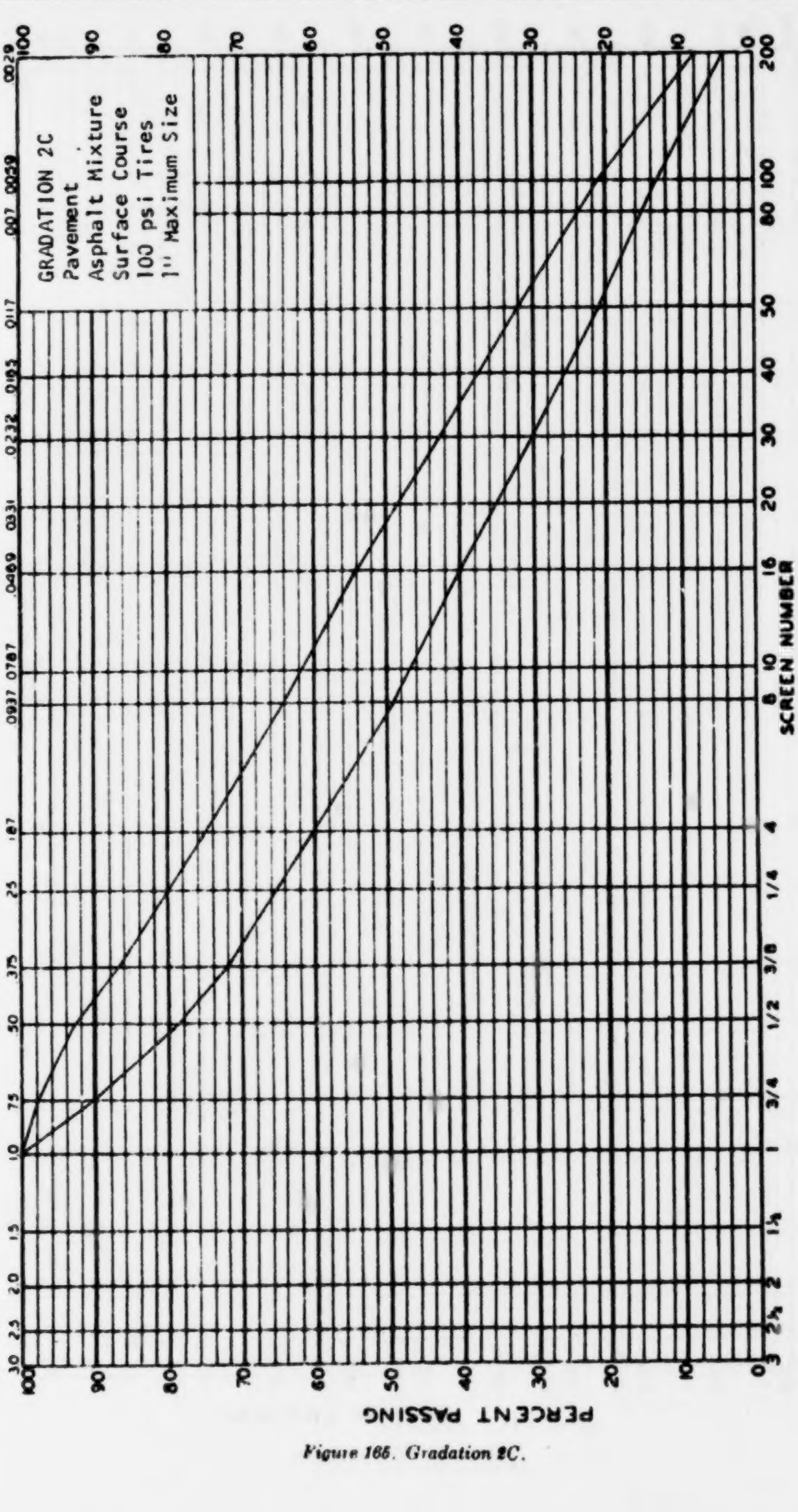


Figure 166. Gradation 2C.

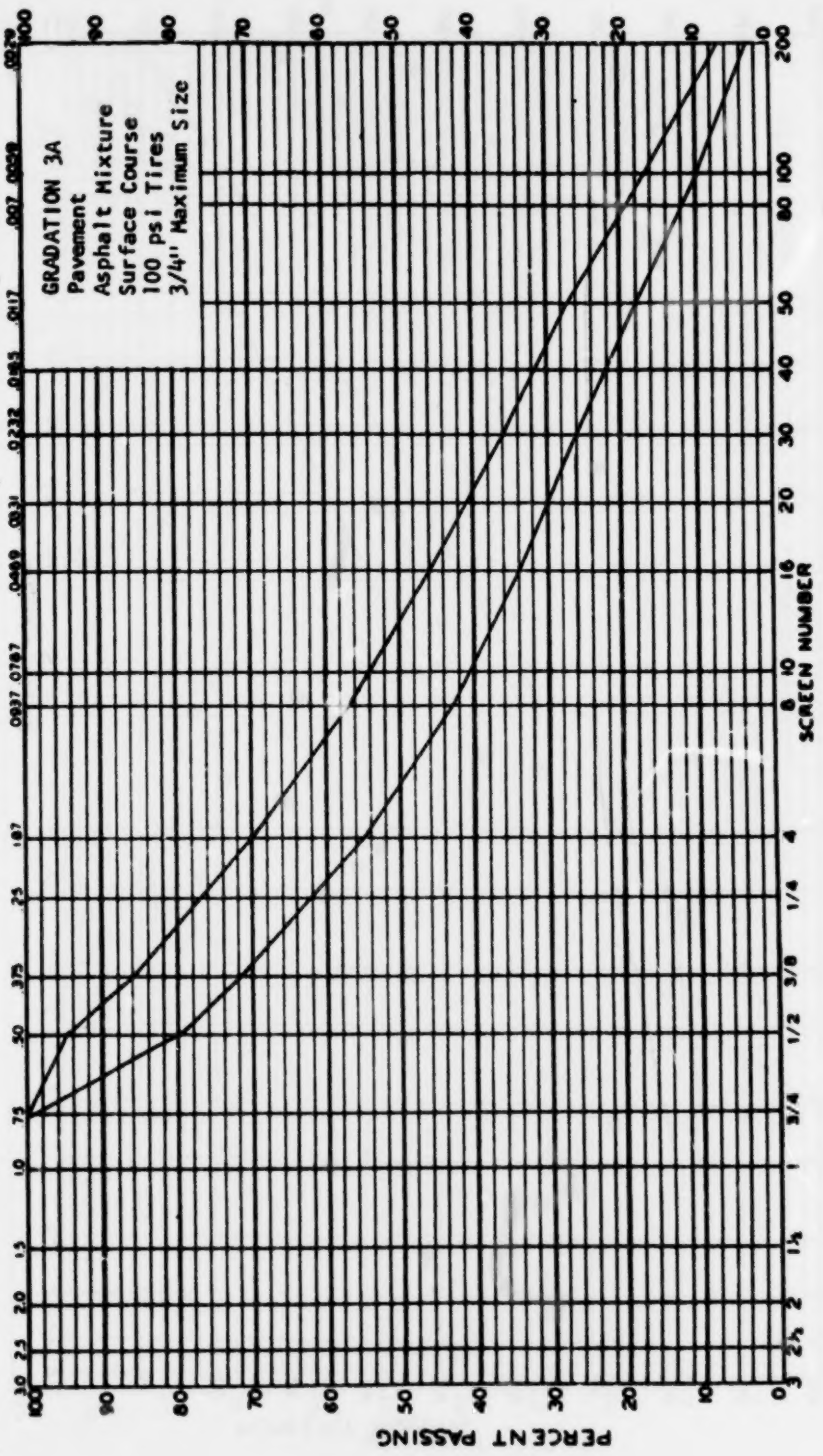


Figure 166. Gradation 3A.

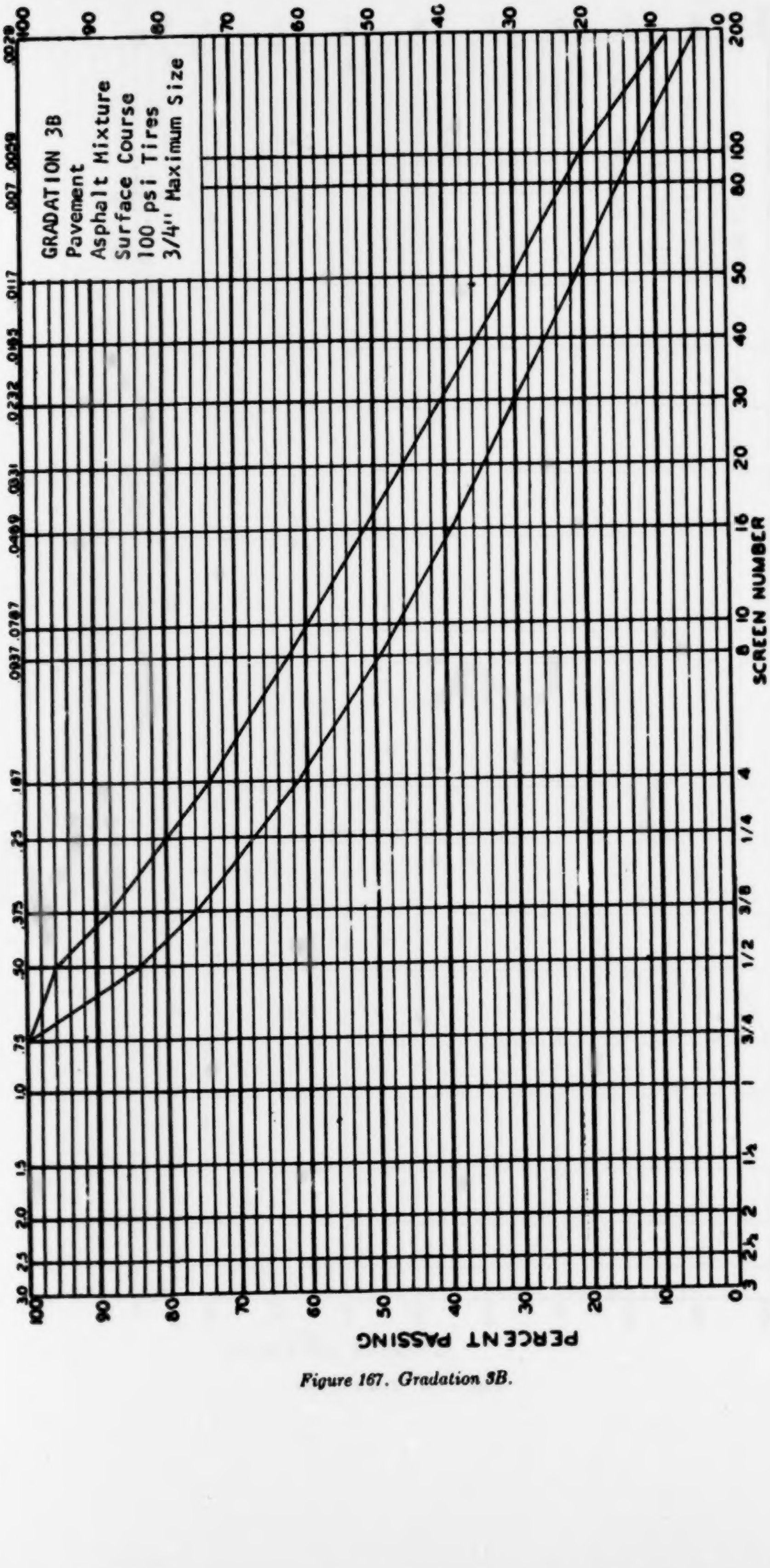


Figure 167. Gradation 3B.

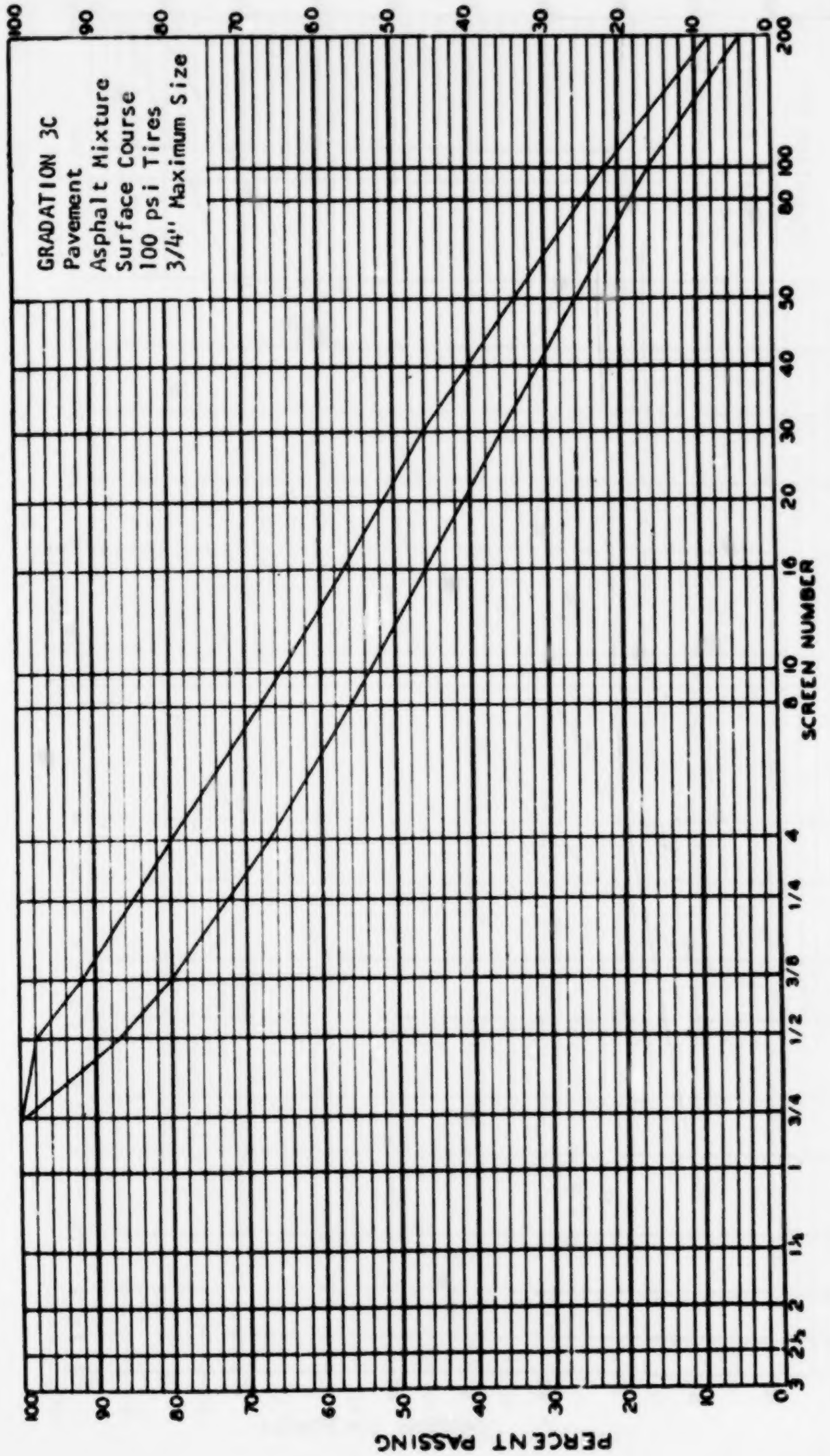


Figure 168. Gradation 3C.

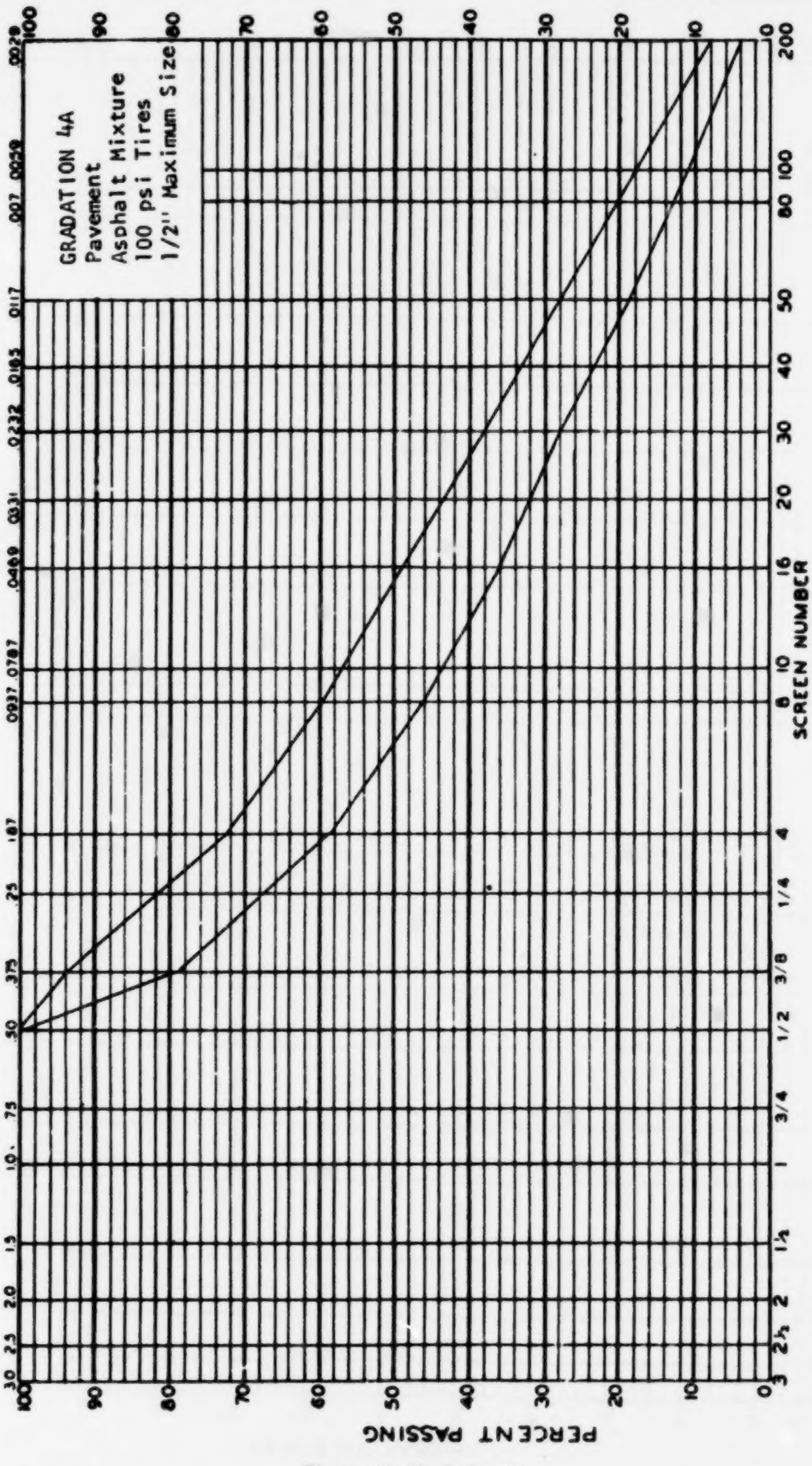


Figure 169. Gradation 4A.

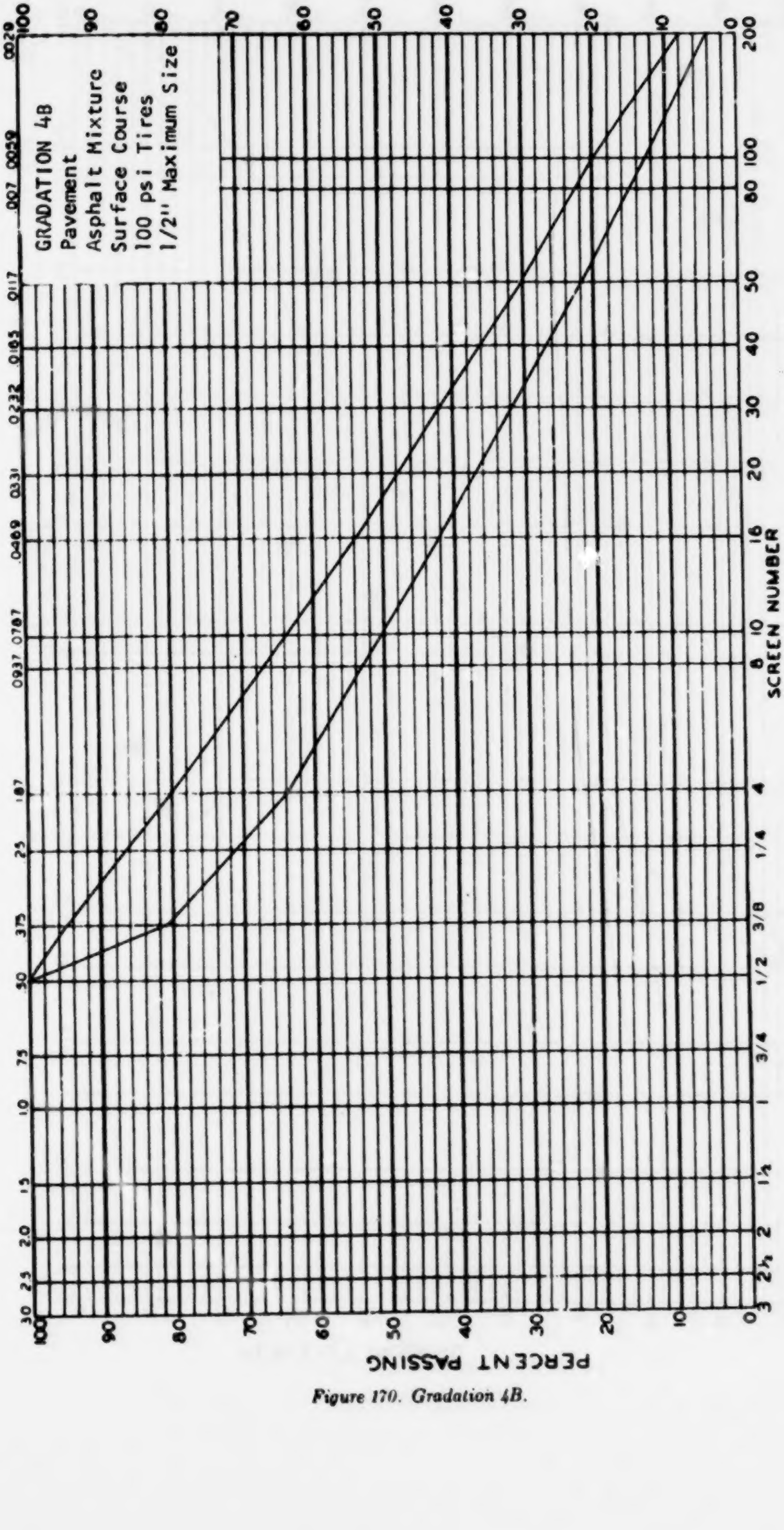


Figure 170. Gradation 4B.

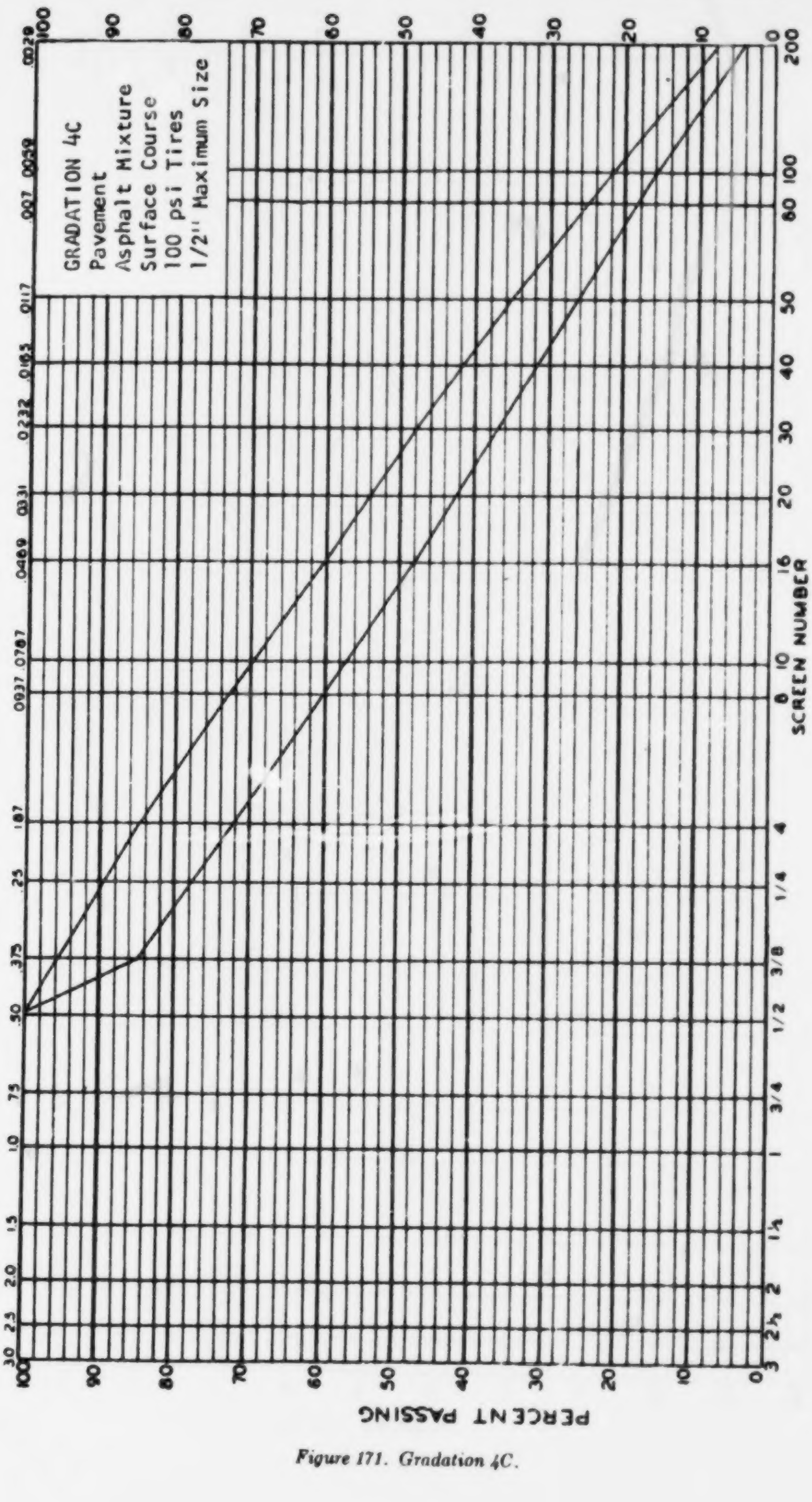


Figure 171. Gradation 4C.

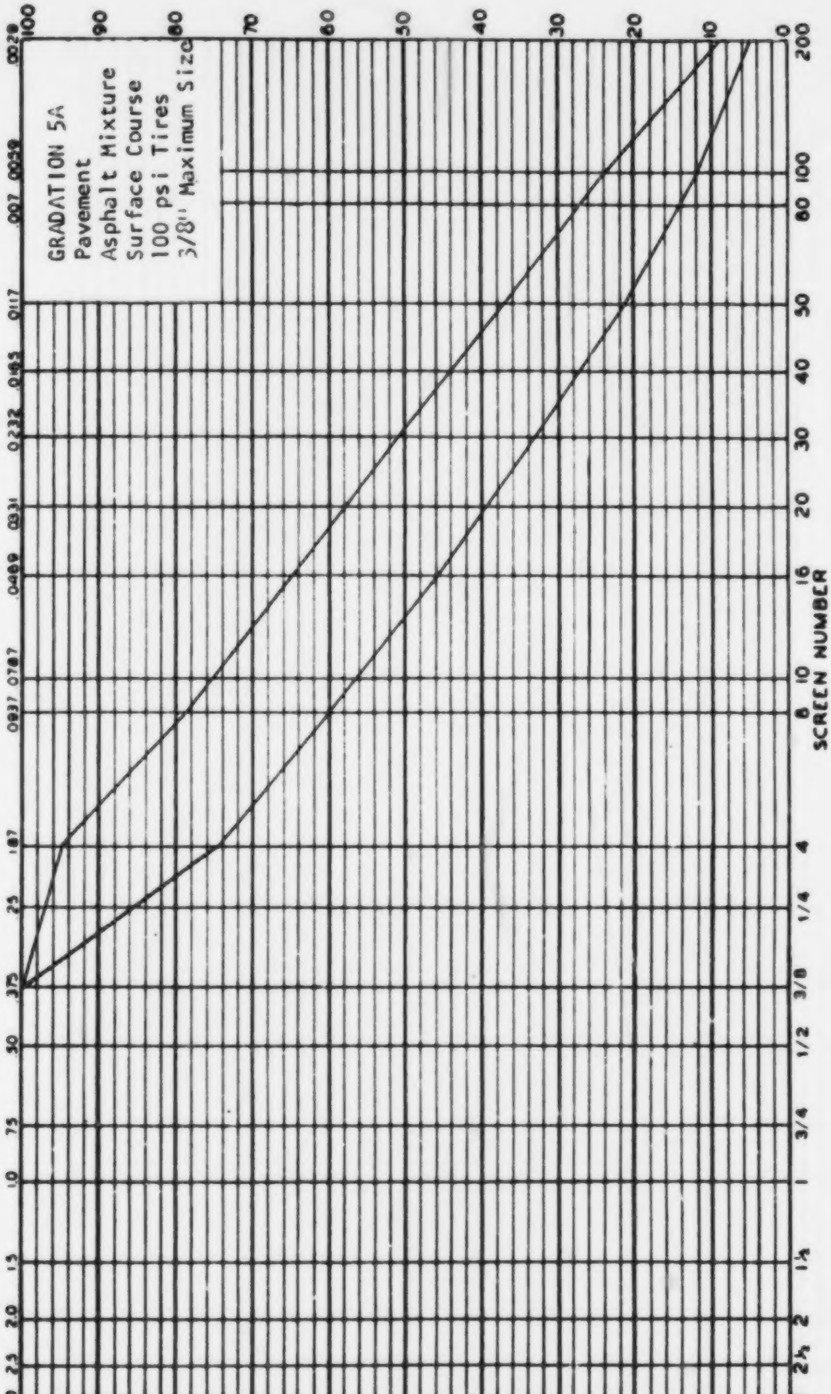


Figure 172. Gradation 5A.

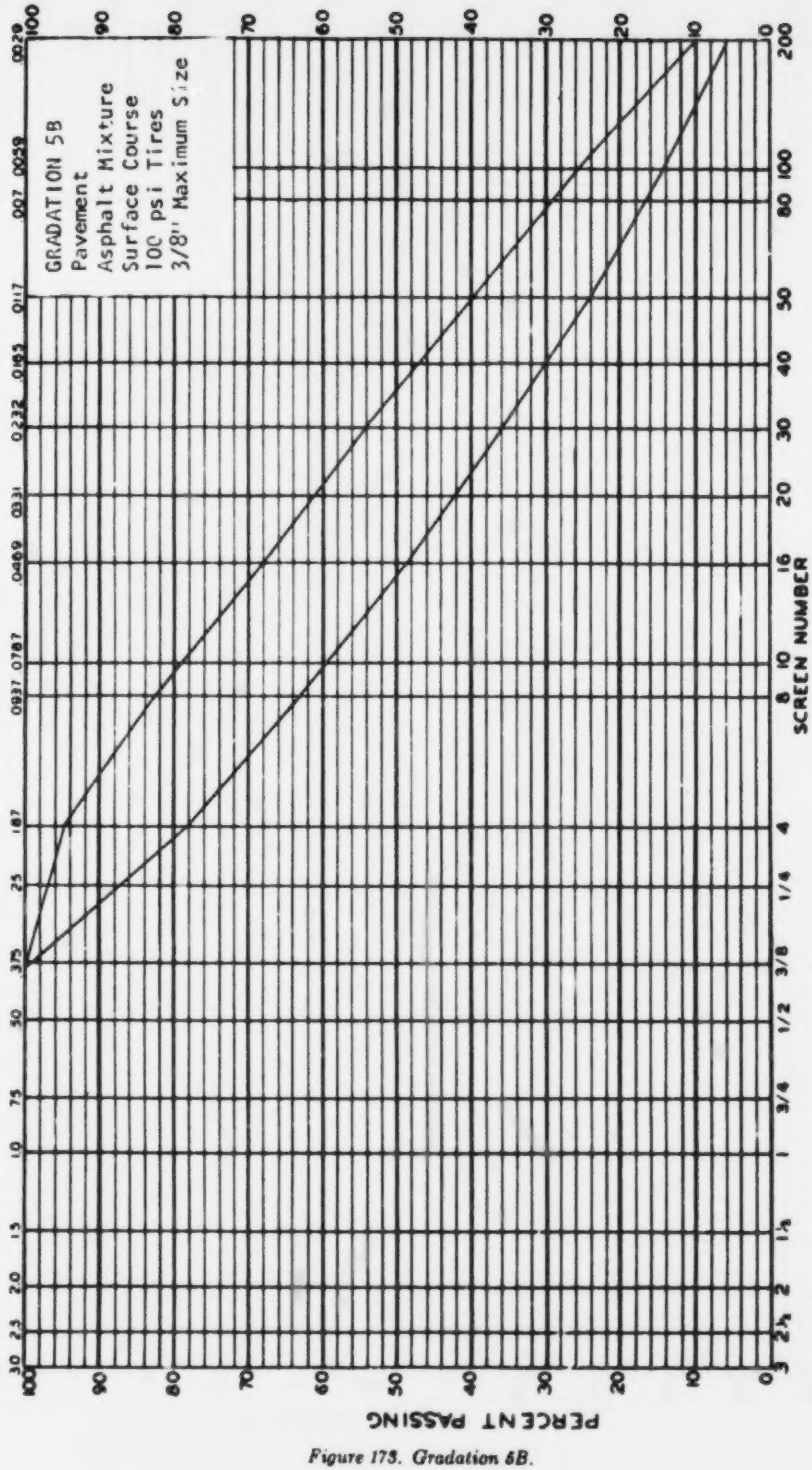


Figure 173. Gradation 5B.

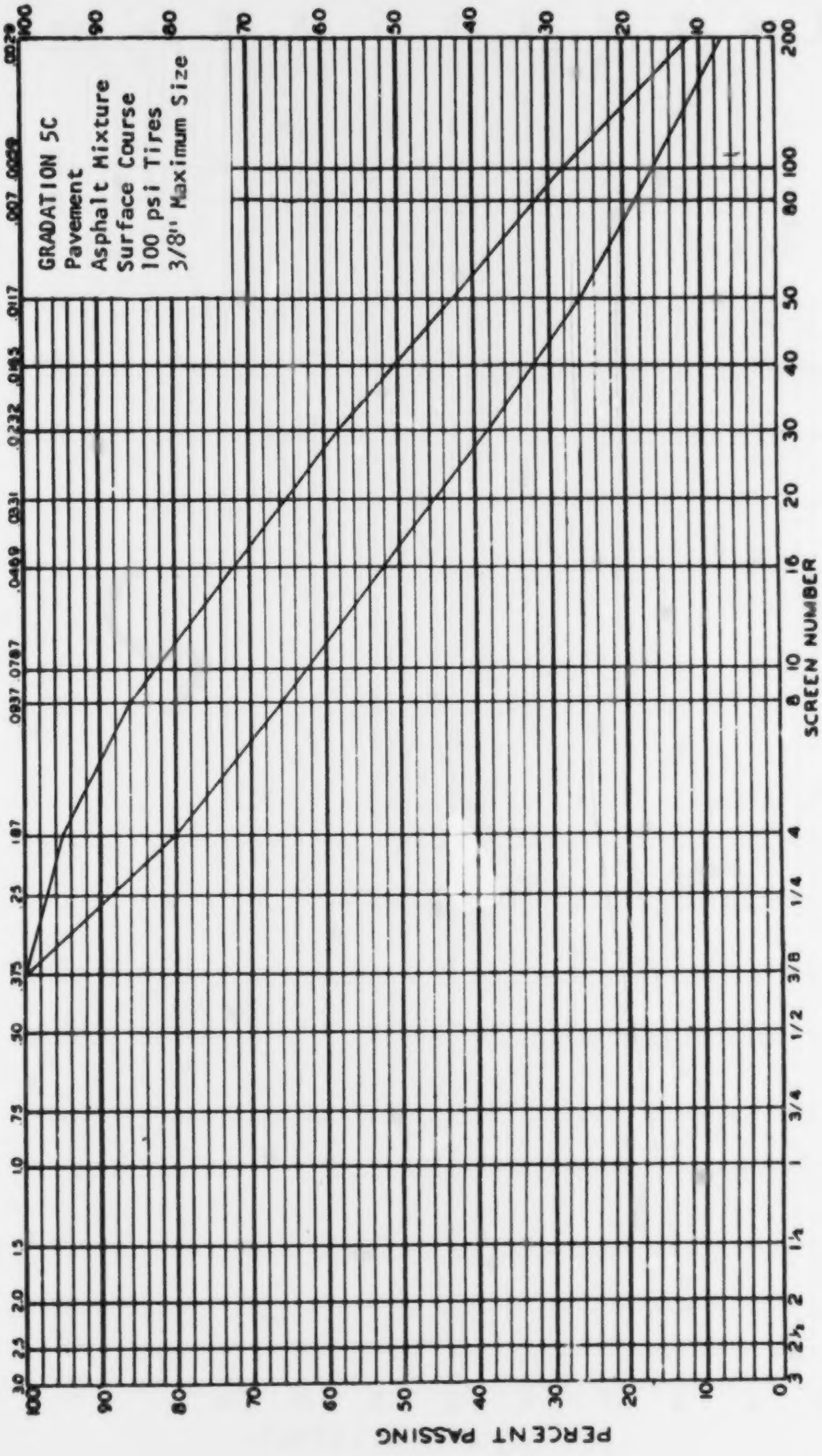


Figure 174. Gradation 5C.

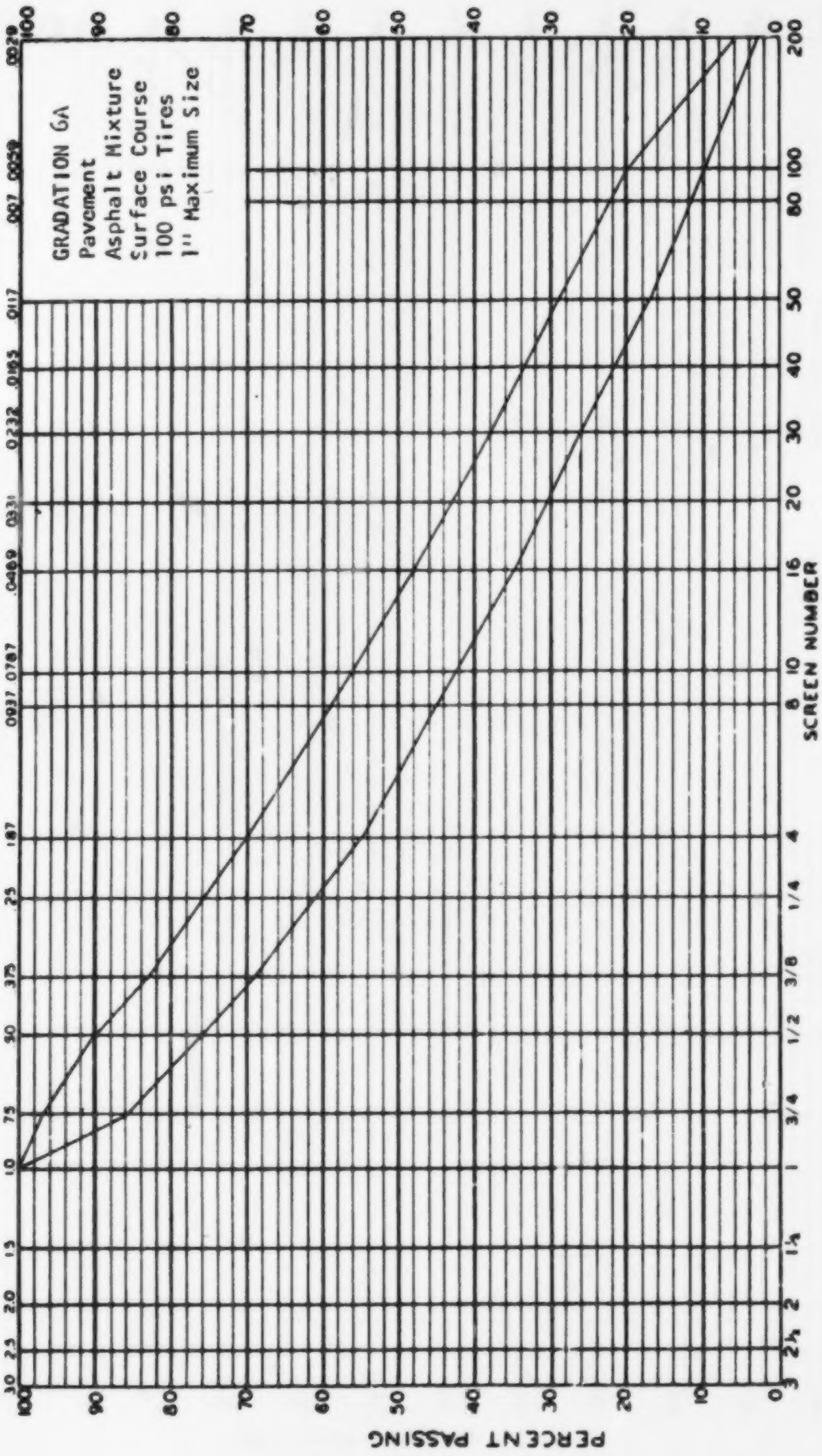


Figure 175. Gradation 6A.

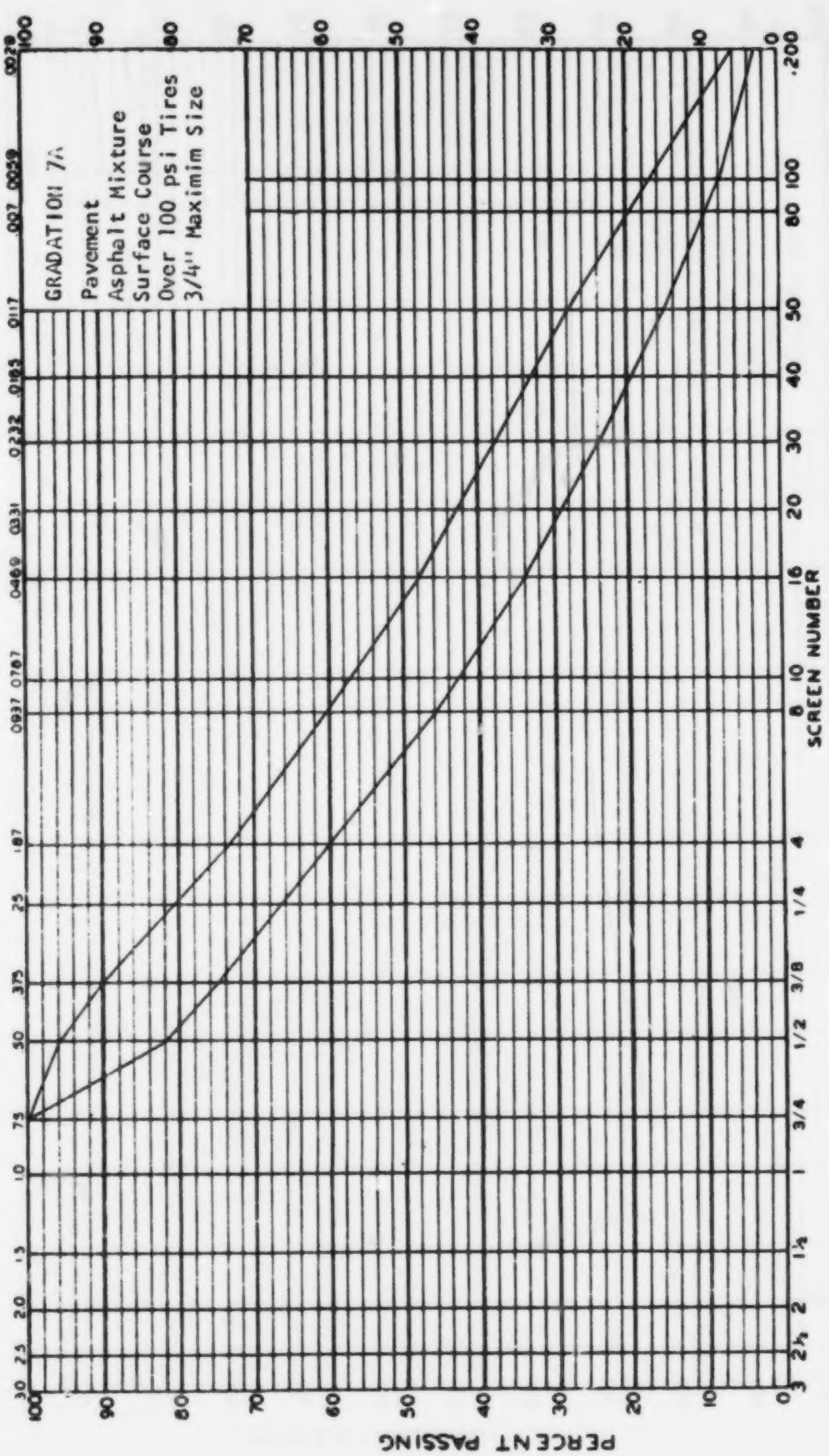


Figure 176. Gradation 7A.

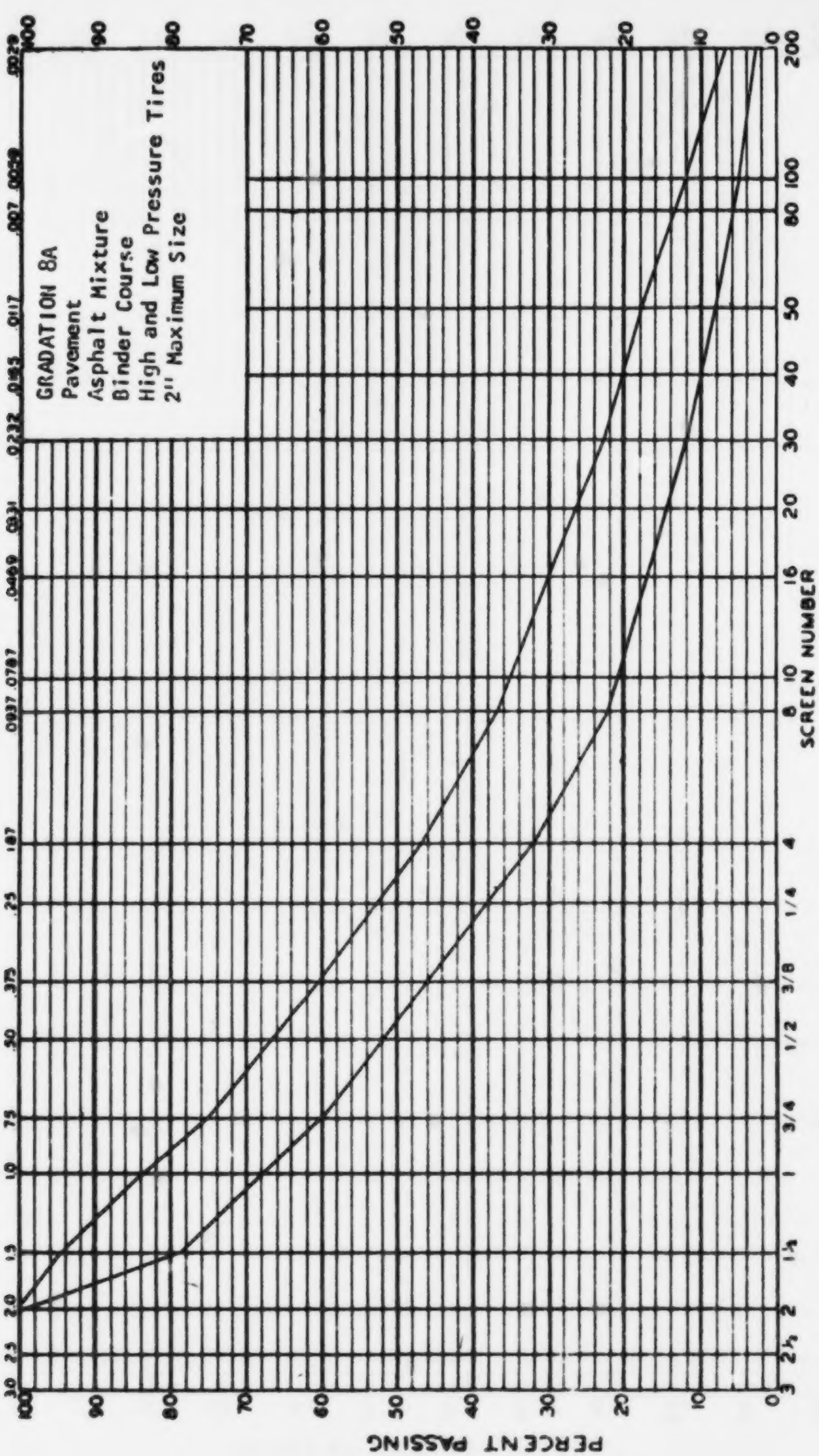


Figure 177. Gradation 8A.

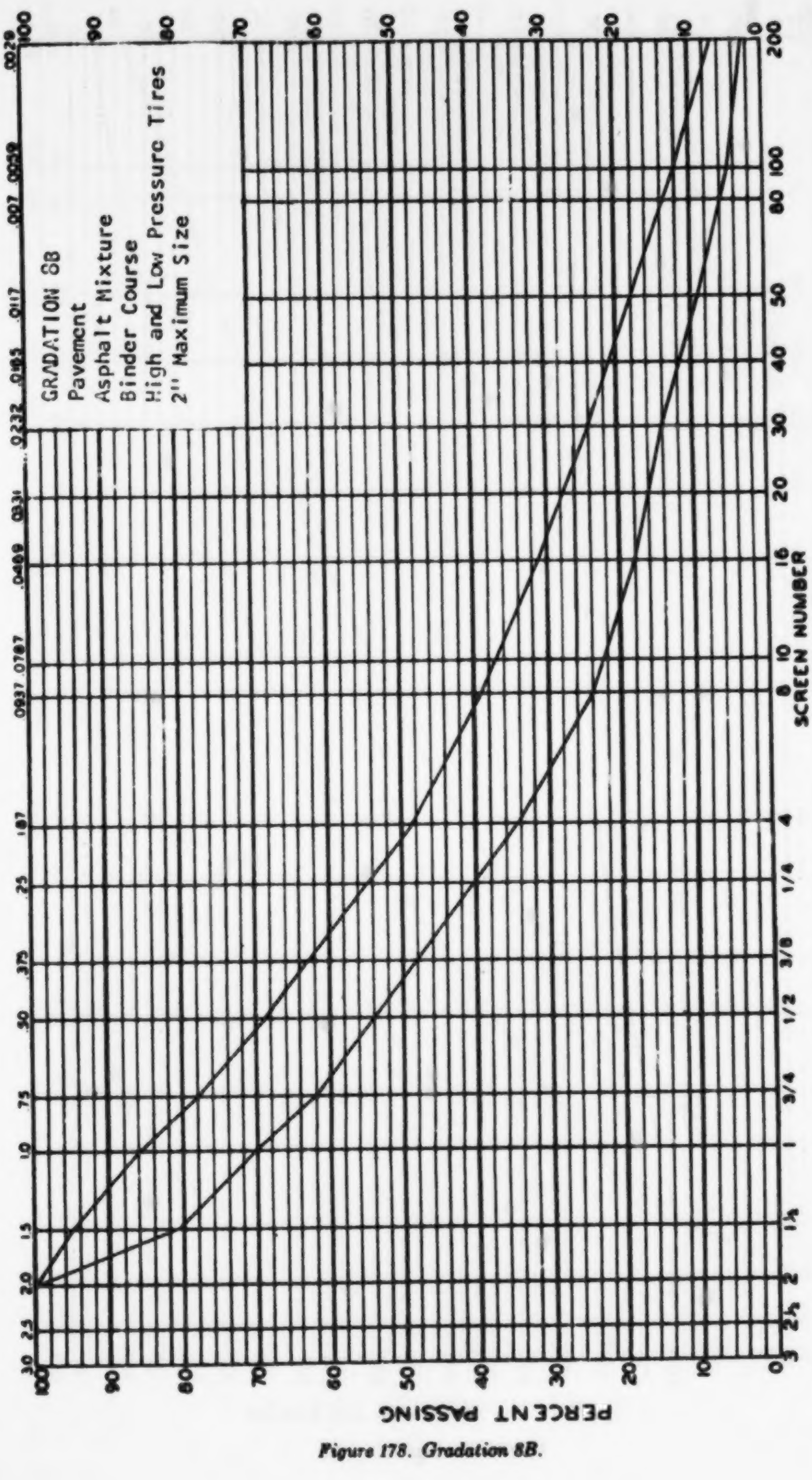


Figure 178. Gradation 8B.

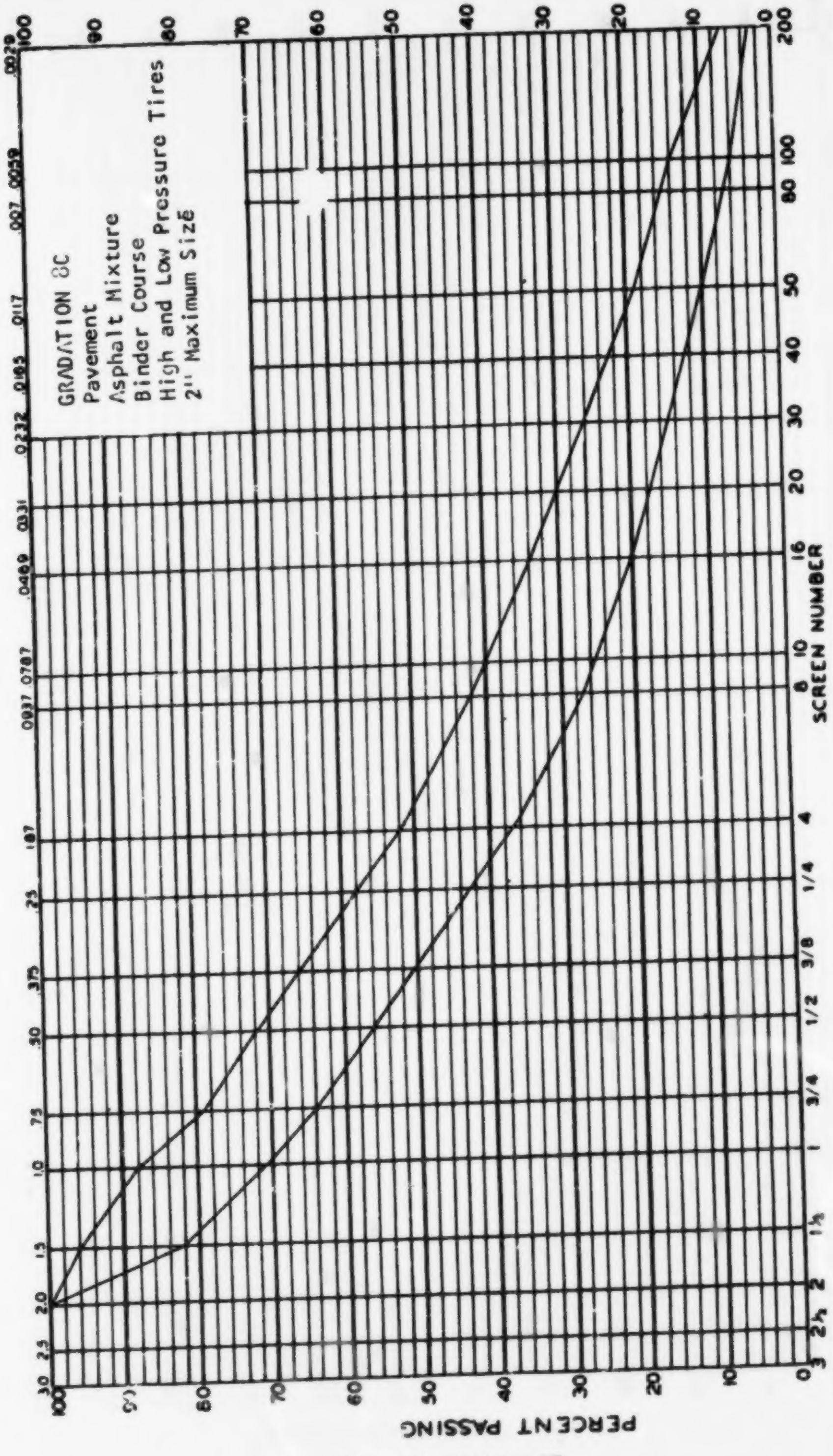


Figure 179. Gradation 8C.

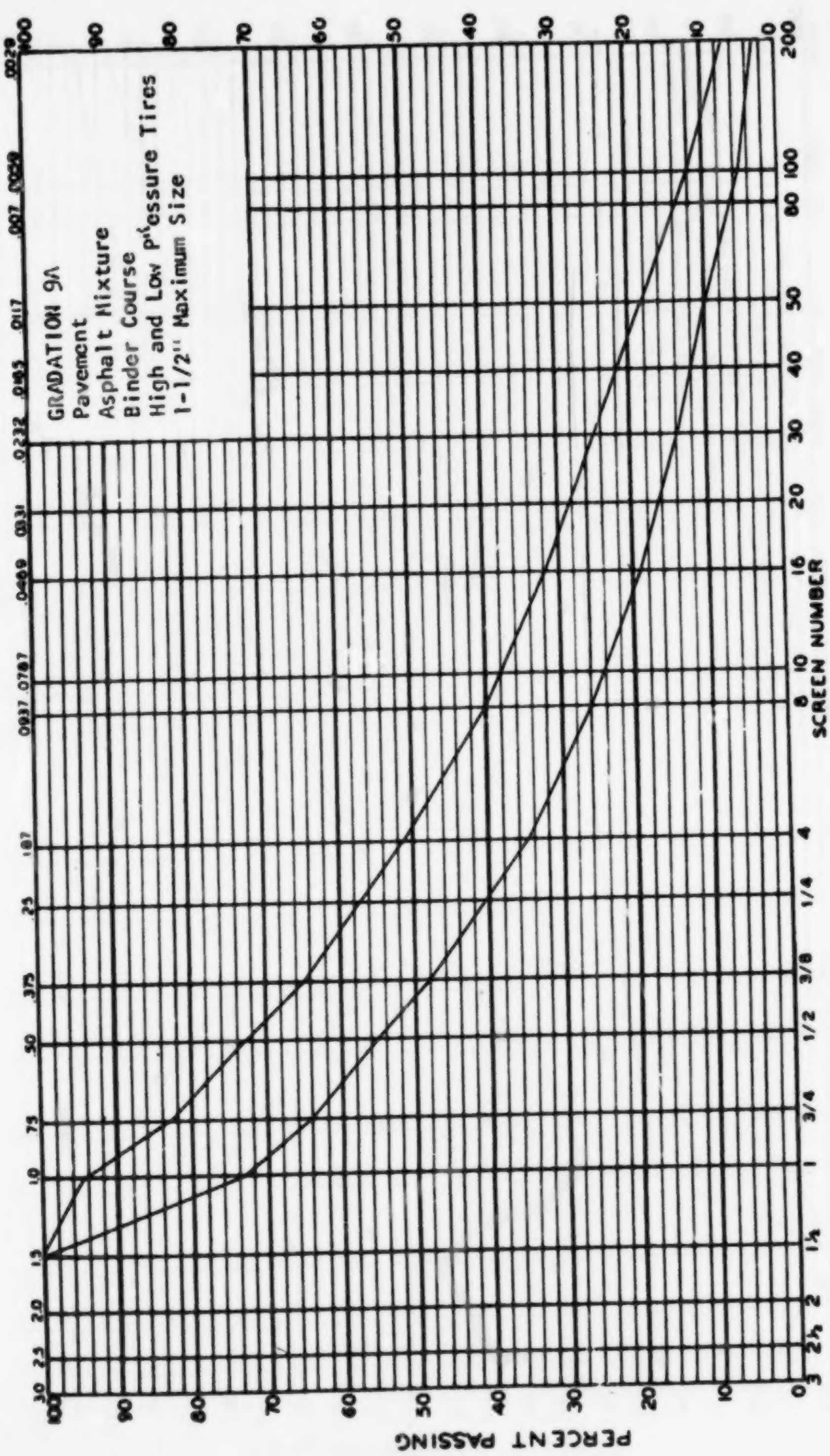


Figure 180. Gradation 9A.

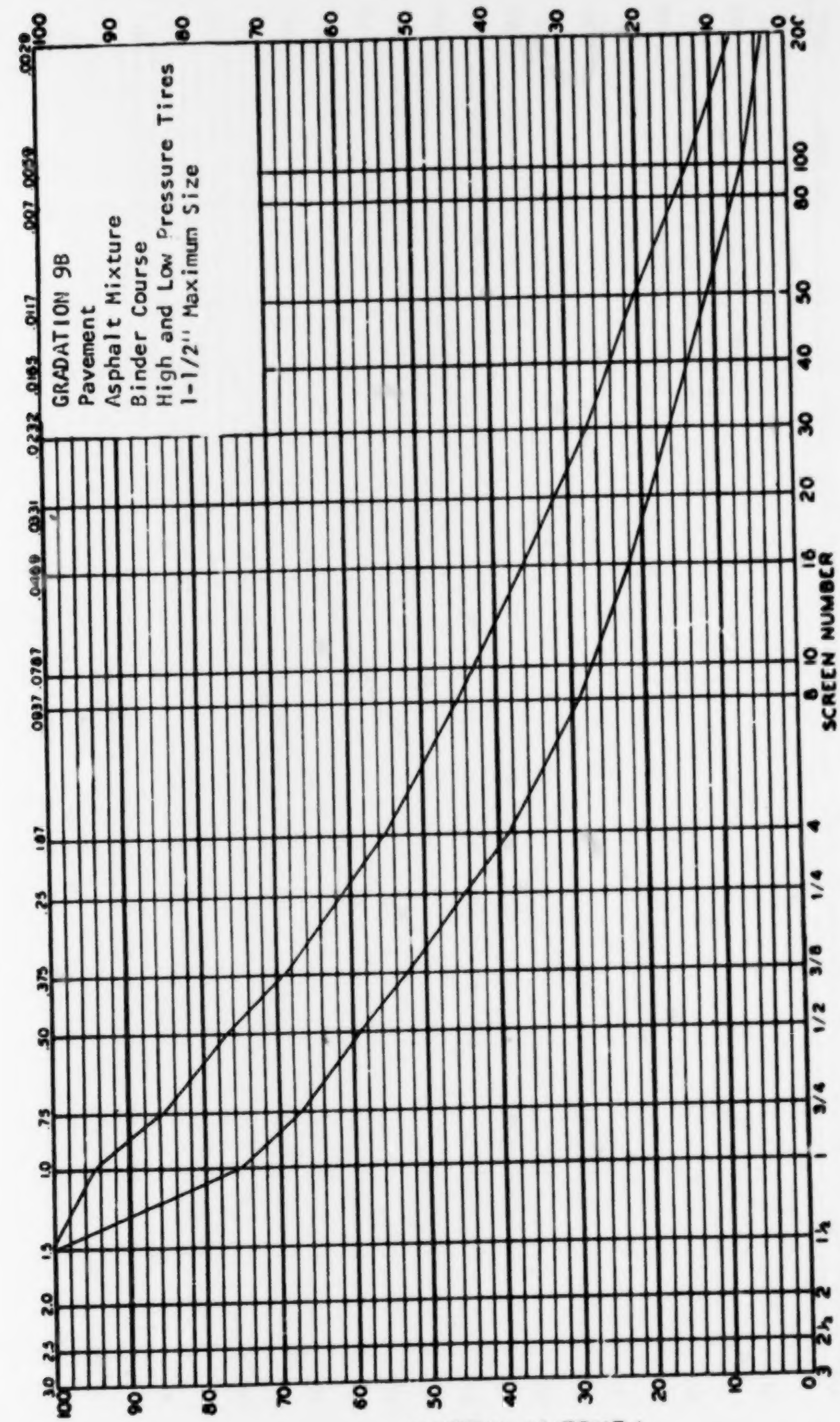


Figure 181. Gradation 9B.

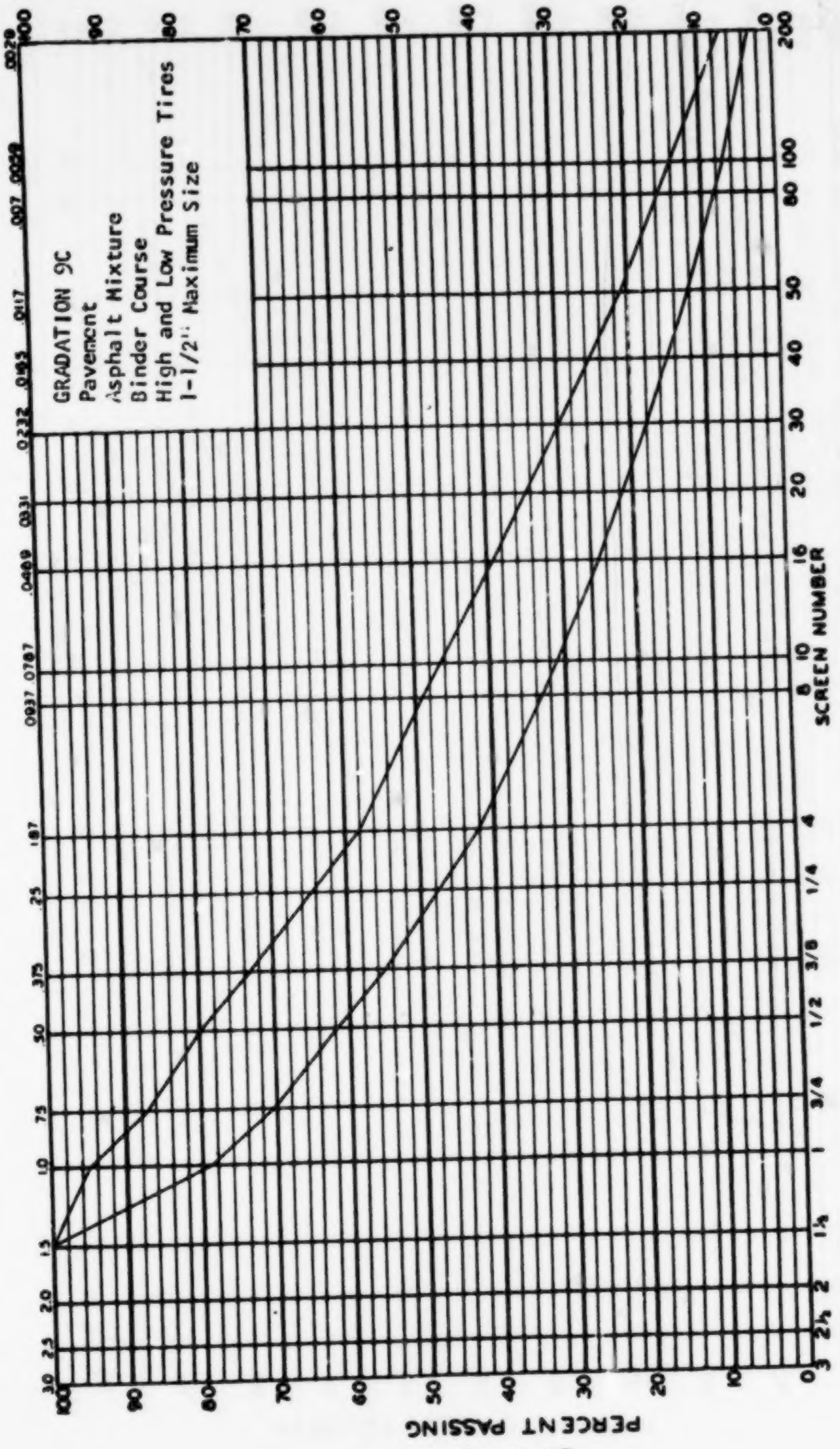


Figure 182. Gradation 9C.

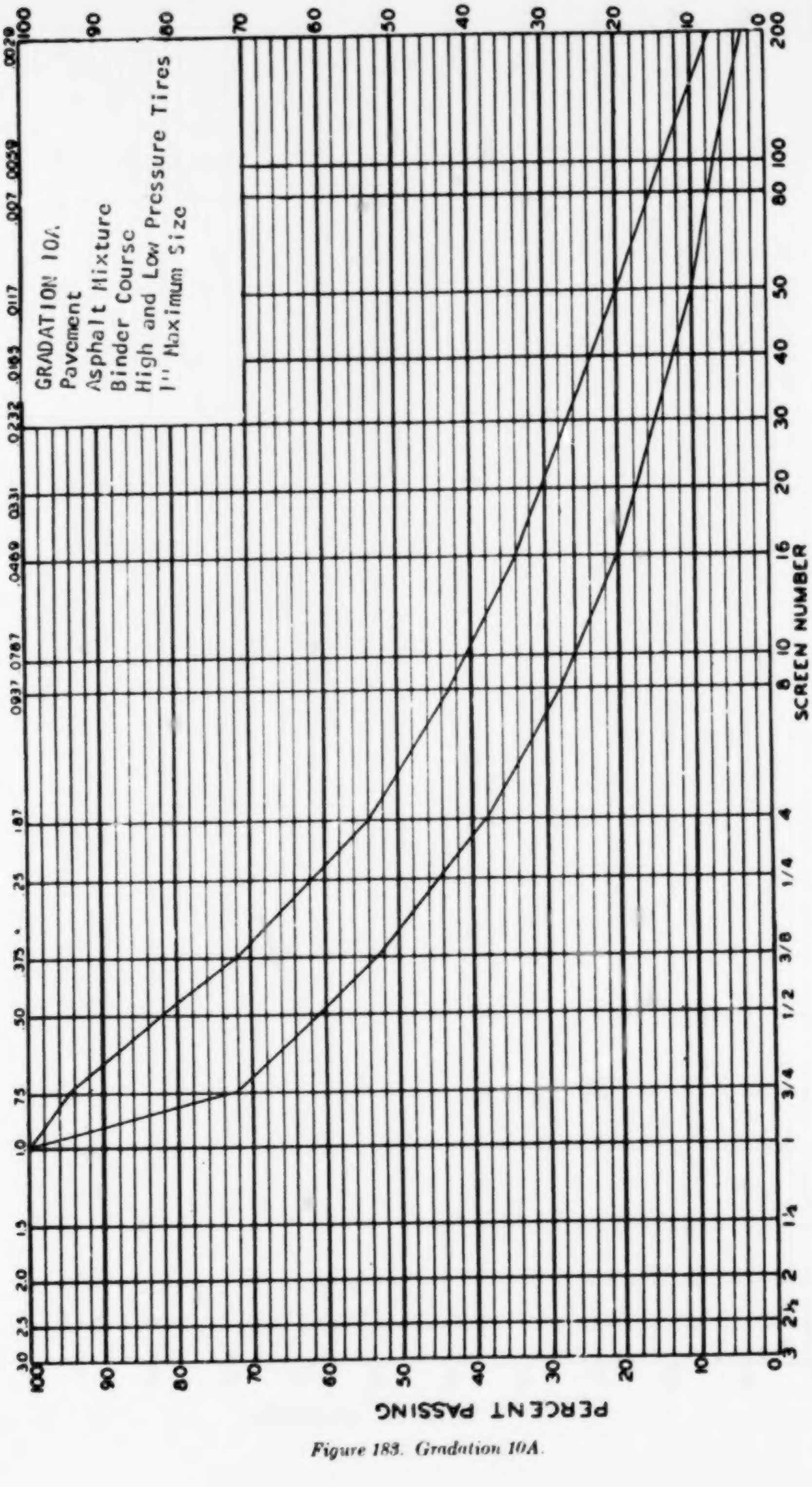


Figure 183. Gradation 10A.

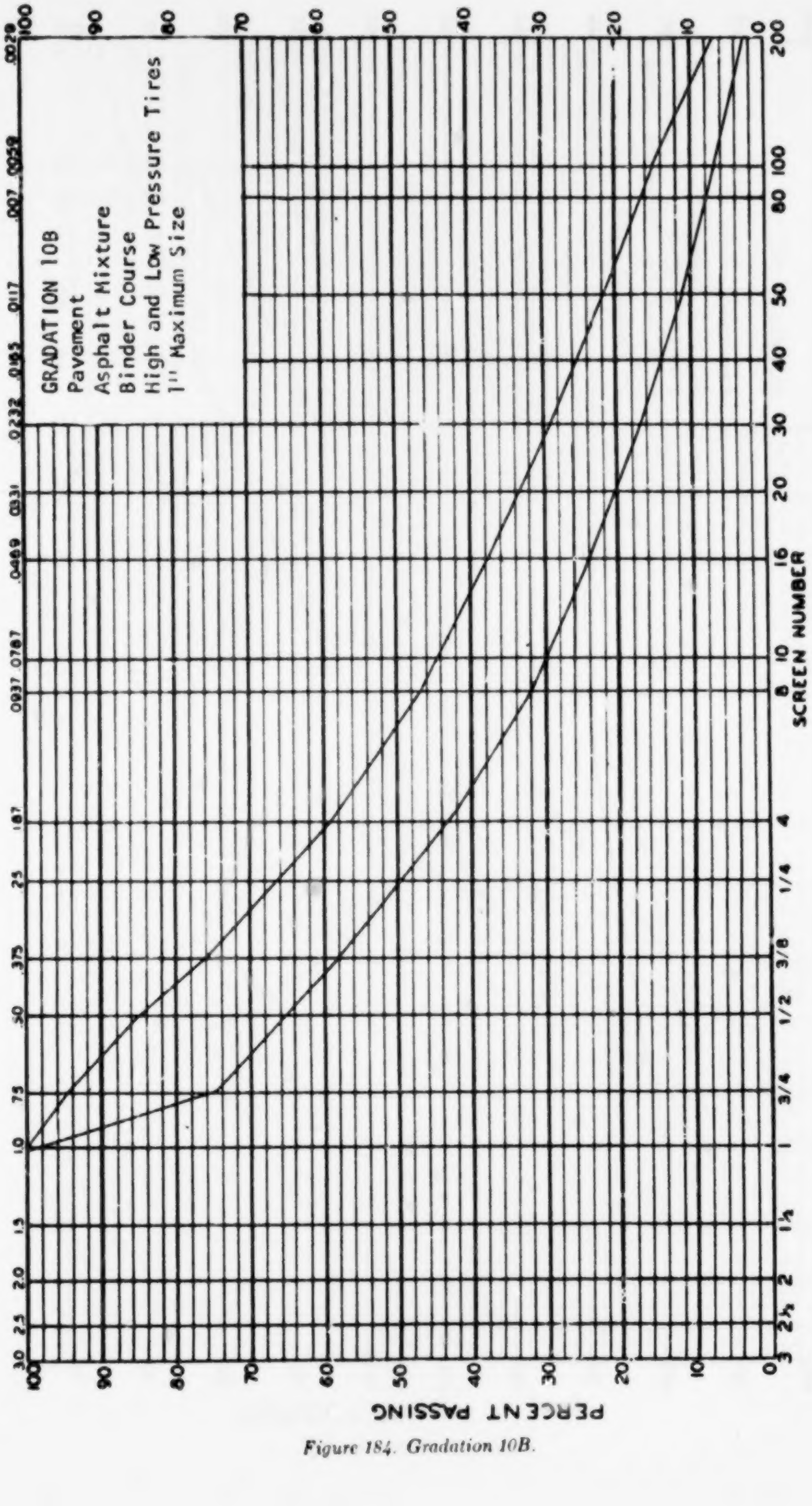


Figure 184. Gradation 10B.

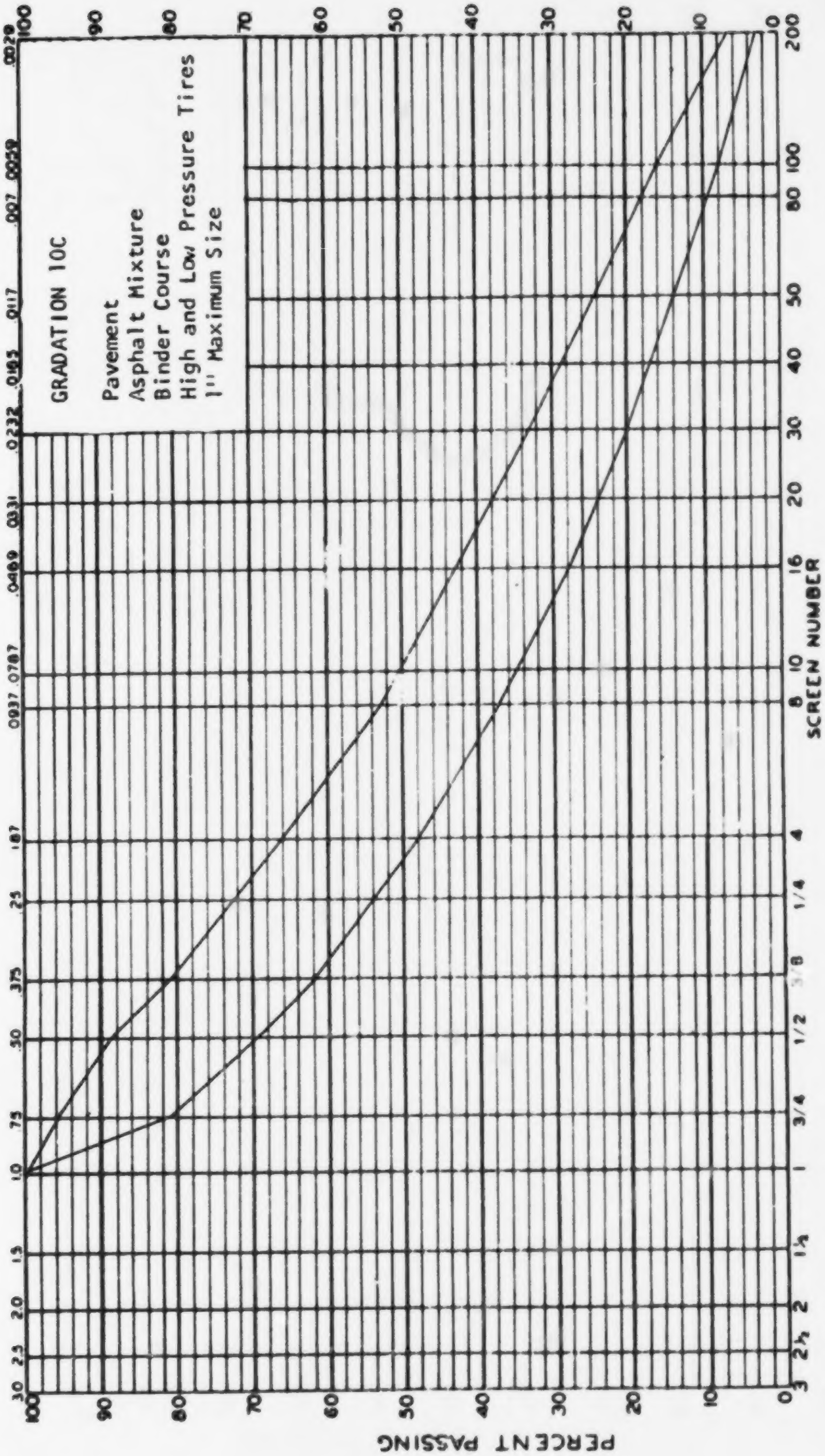


Figure 185. Gradation 10C.

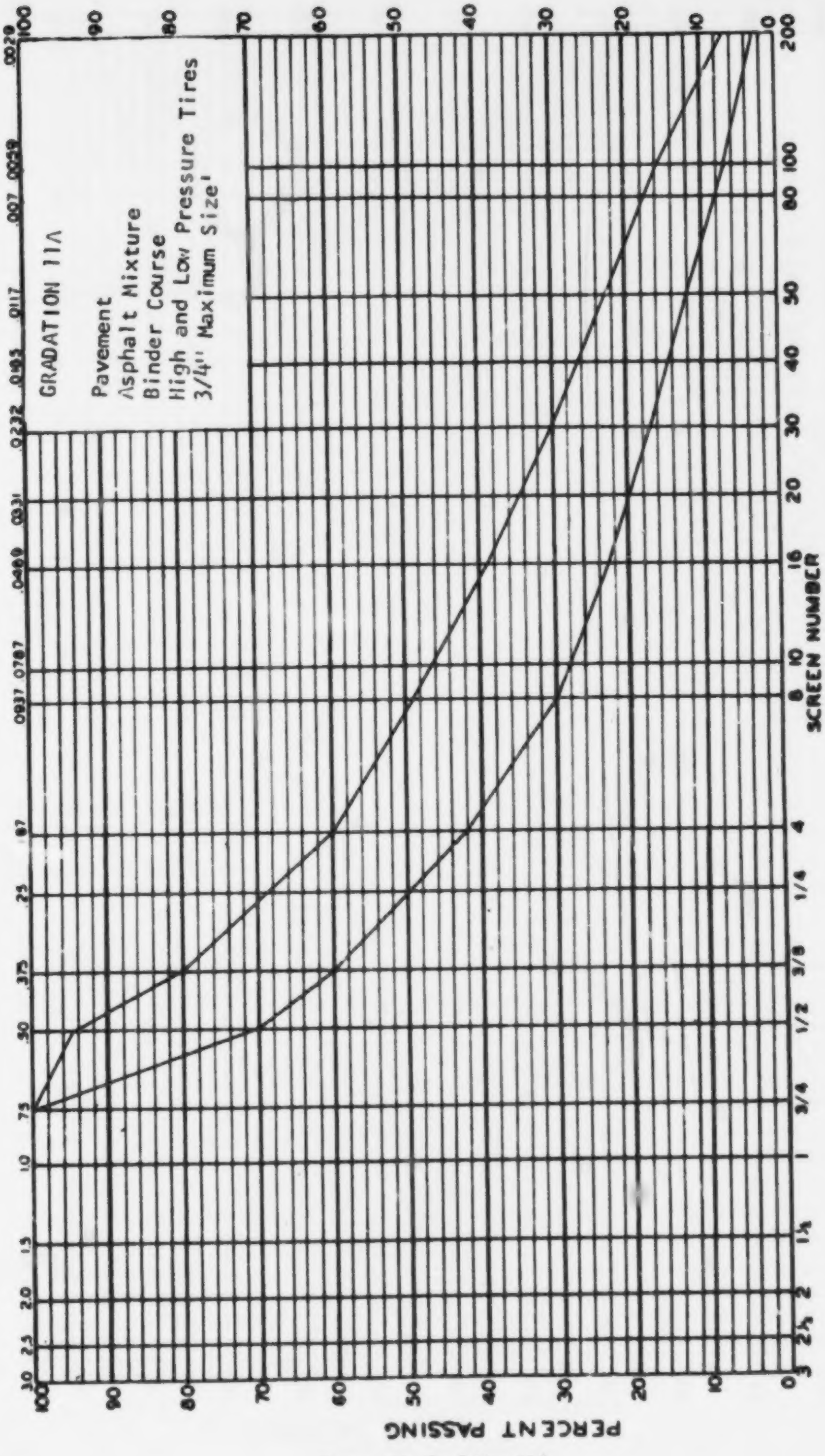


Figure 186. Gradation 11A.

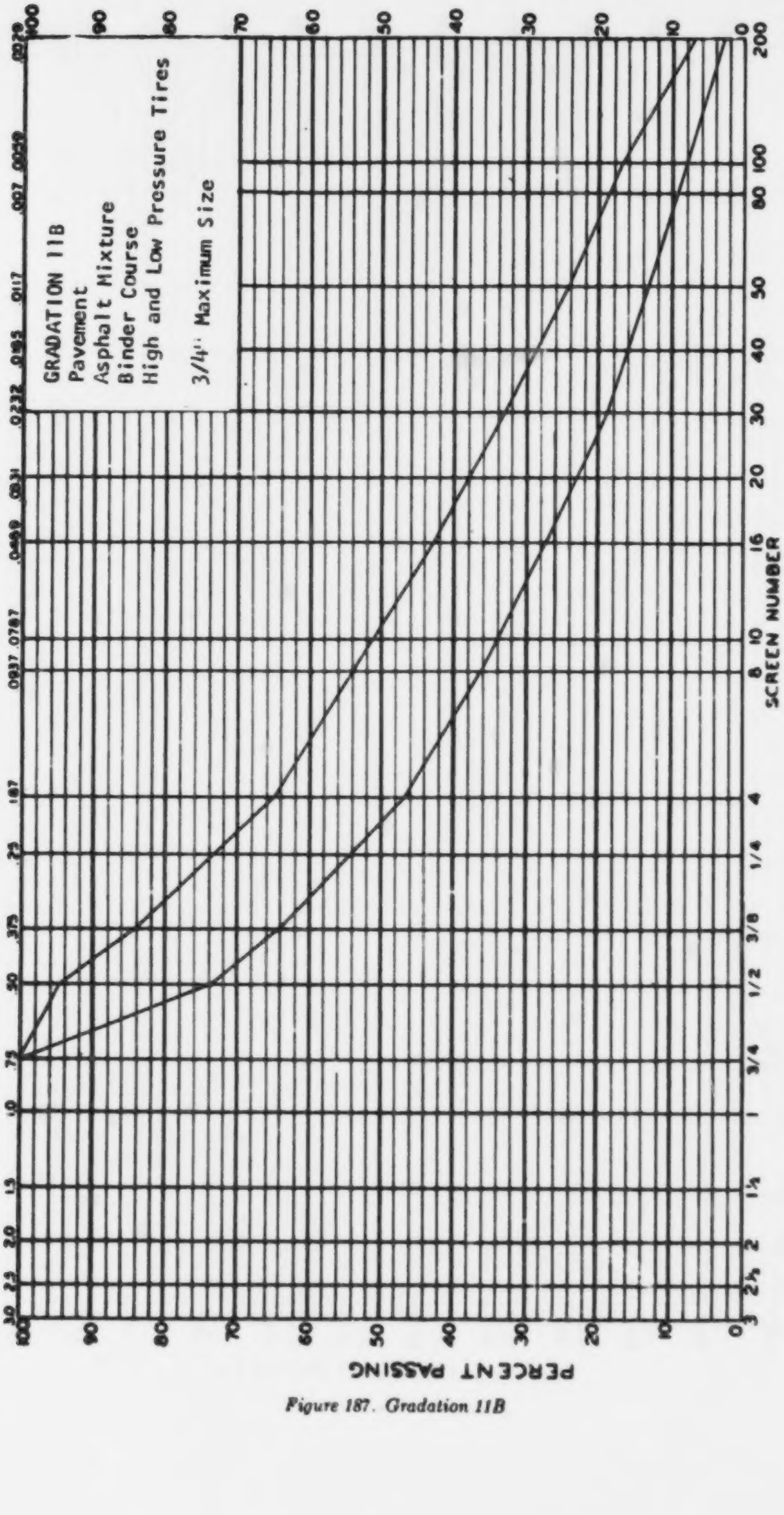


Figure 187. Gradation 11B

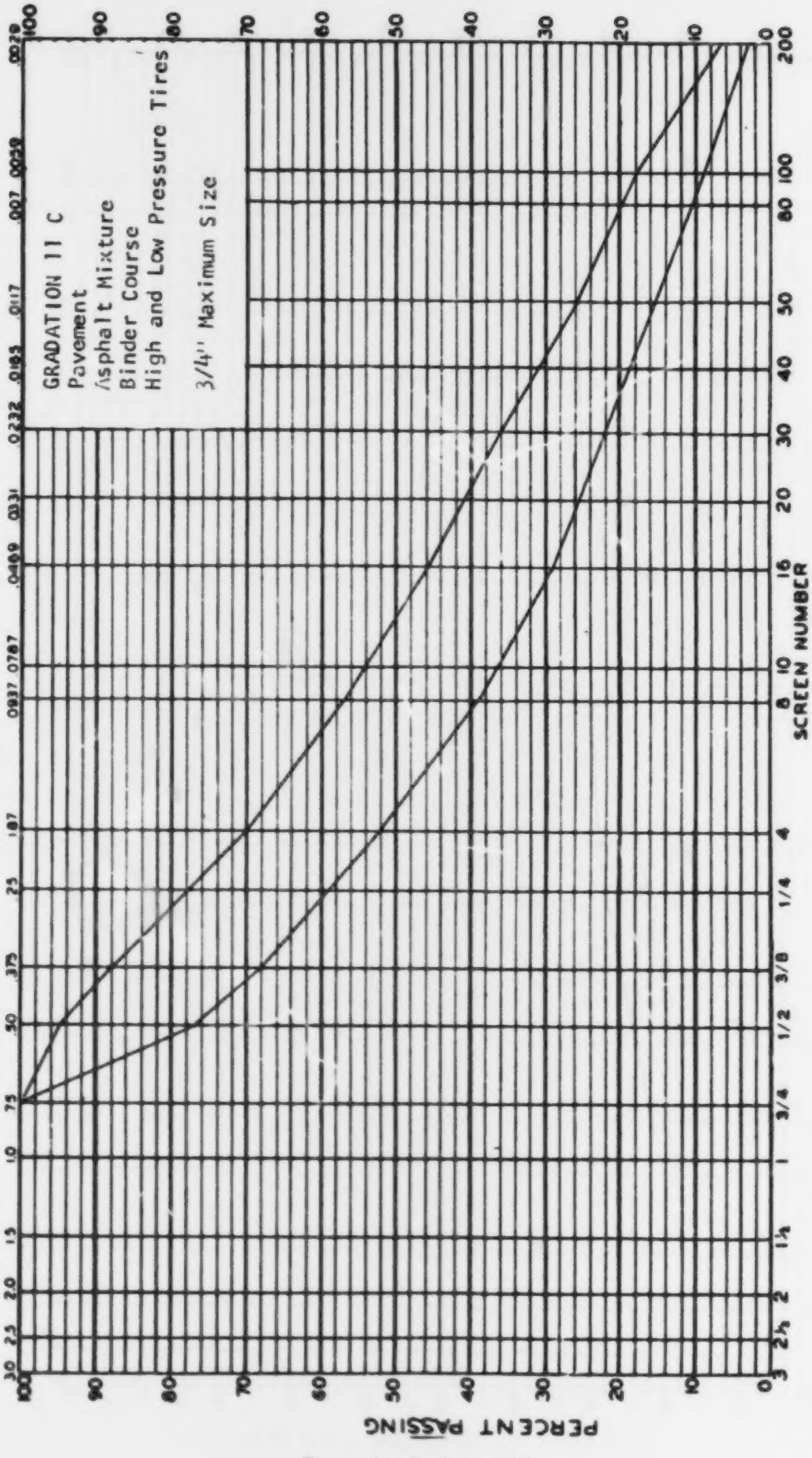


Figure 188. Gradation 11C.

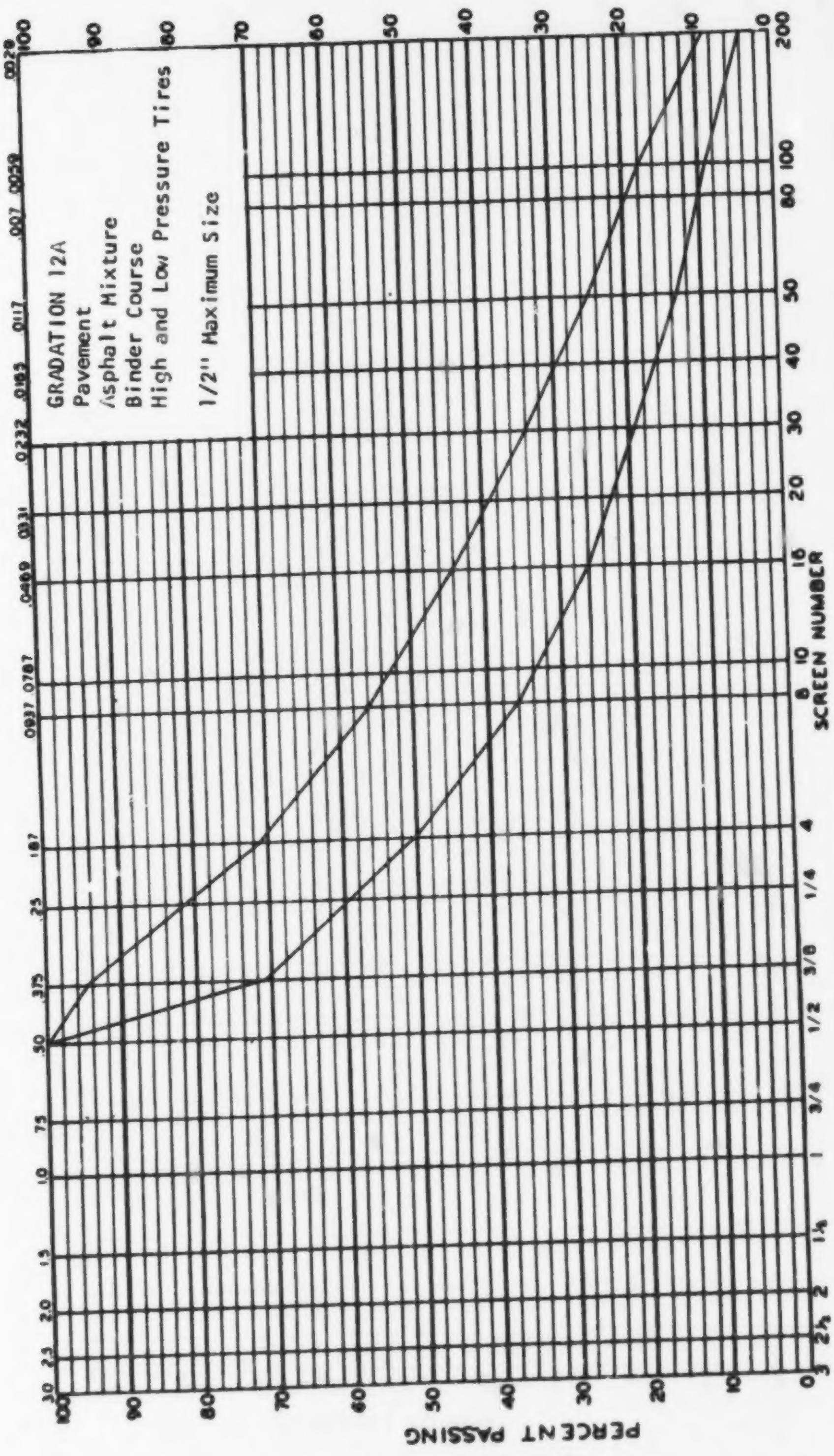


Figure 189. Gradation 12A.

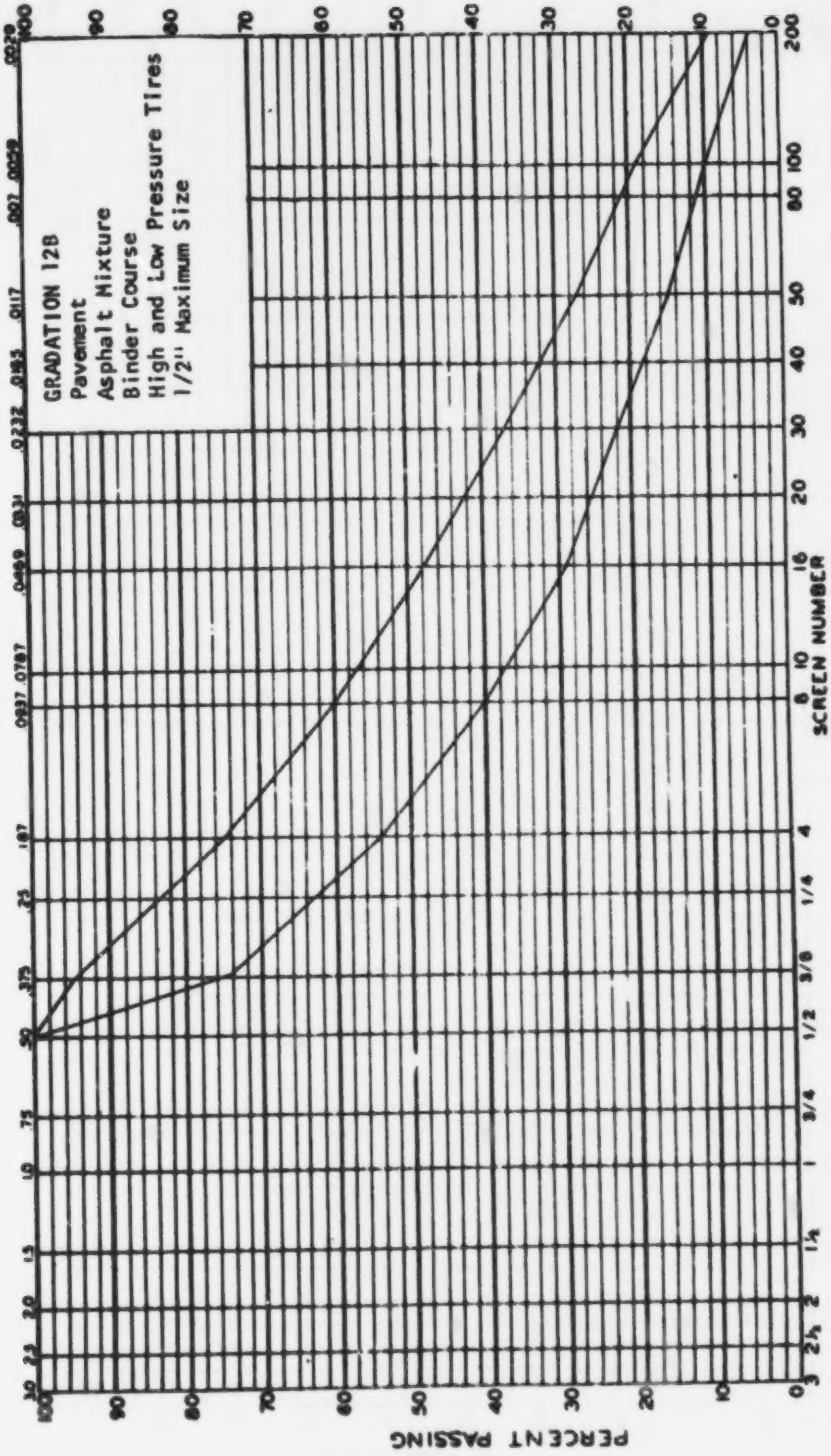


Figure 190. Gradation 12B.

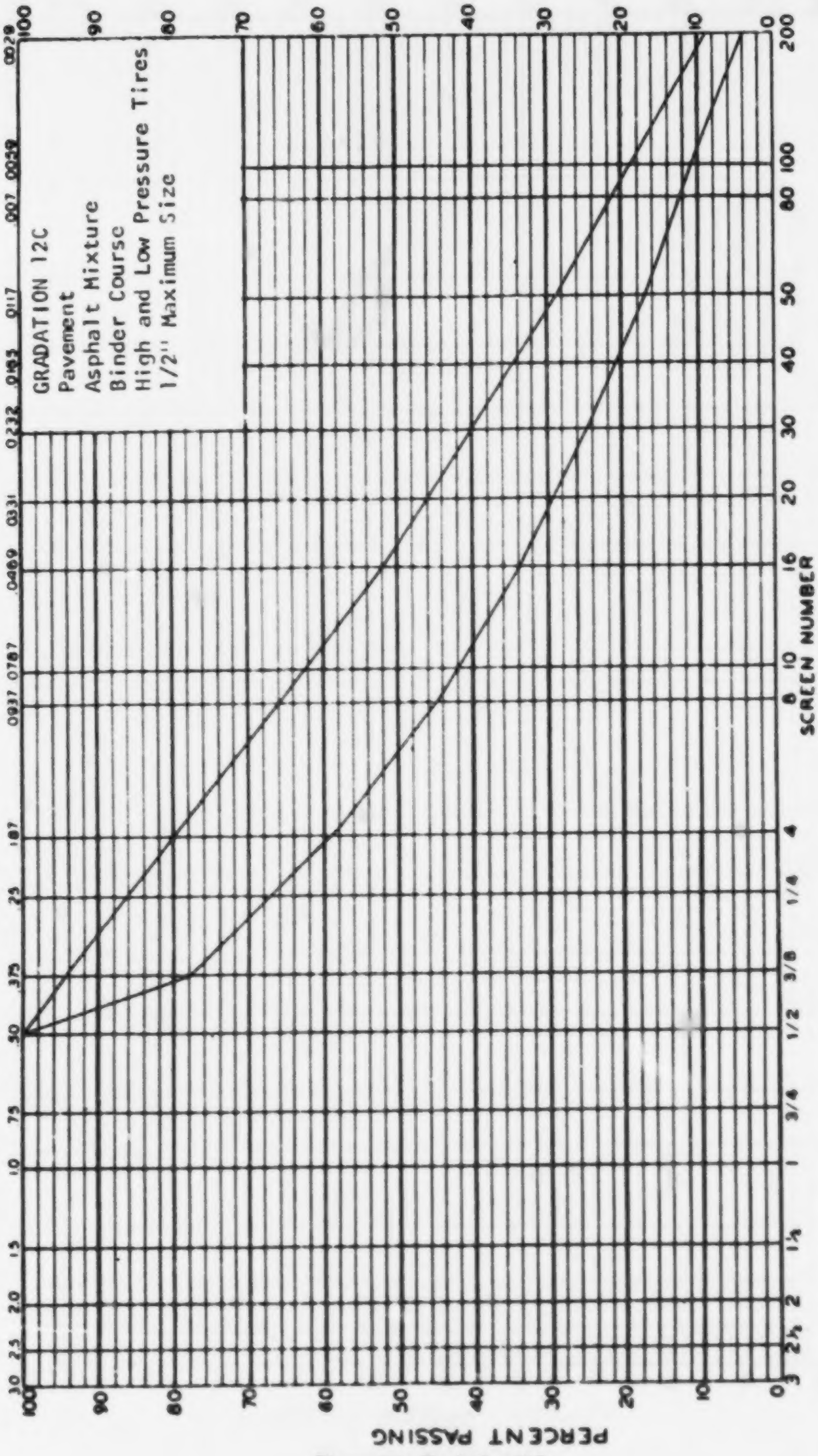


Figure 191. Gradation 12C.

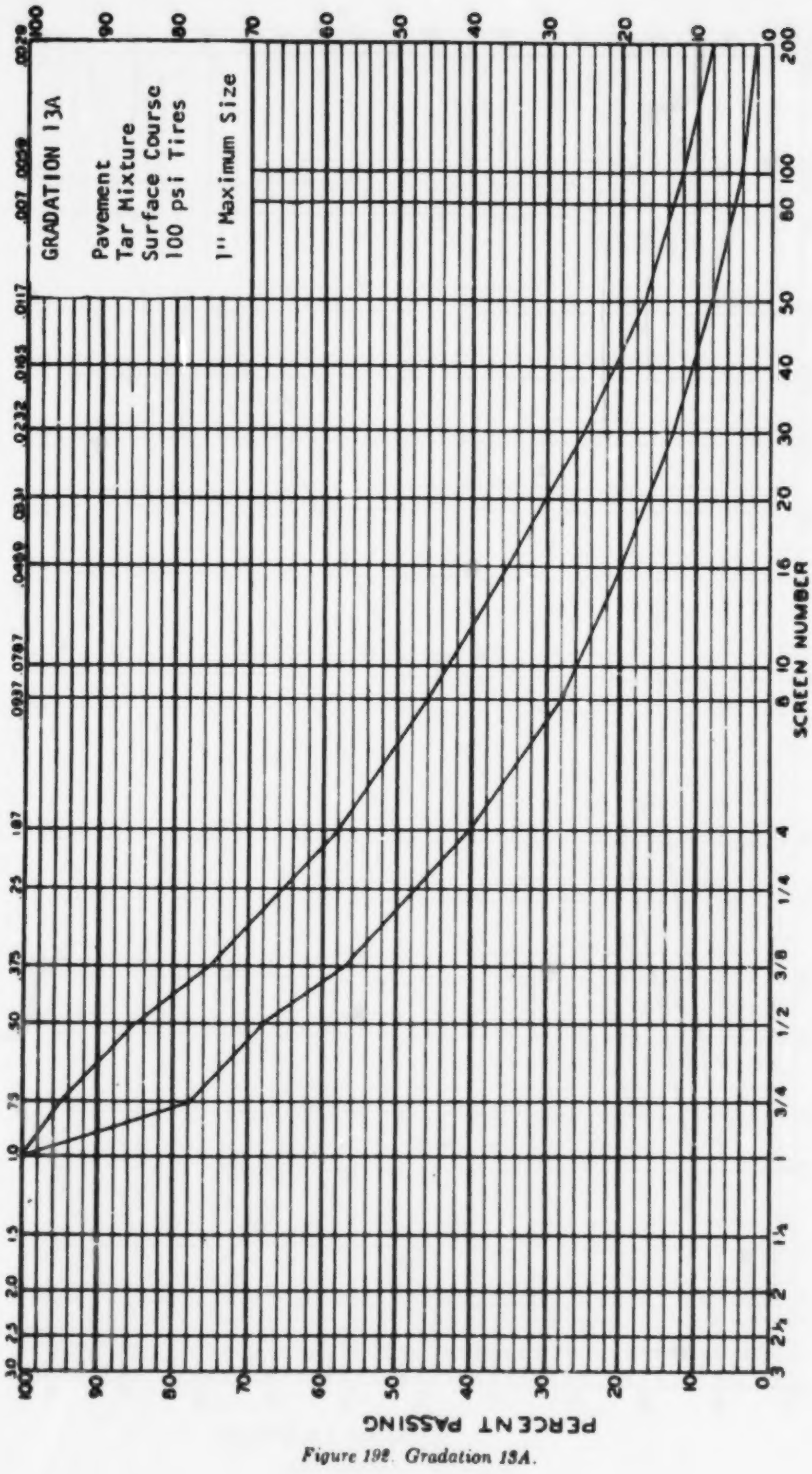


Figure 192. Gradation 13A.

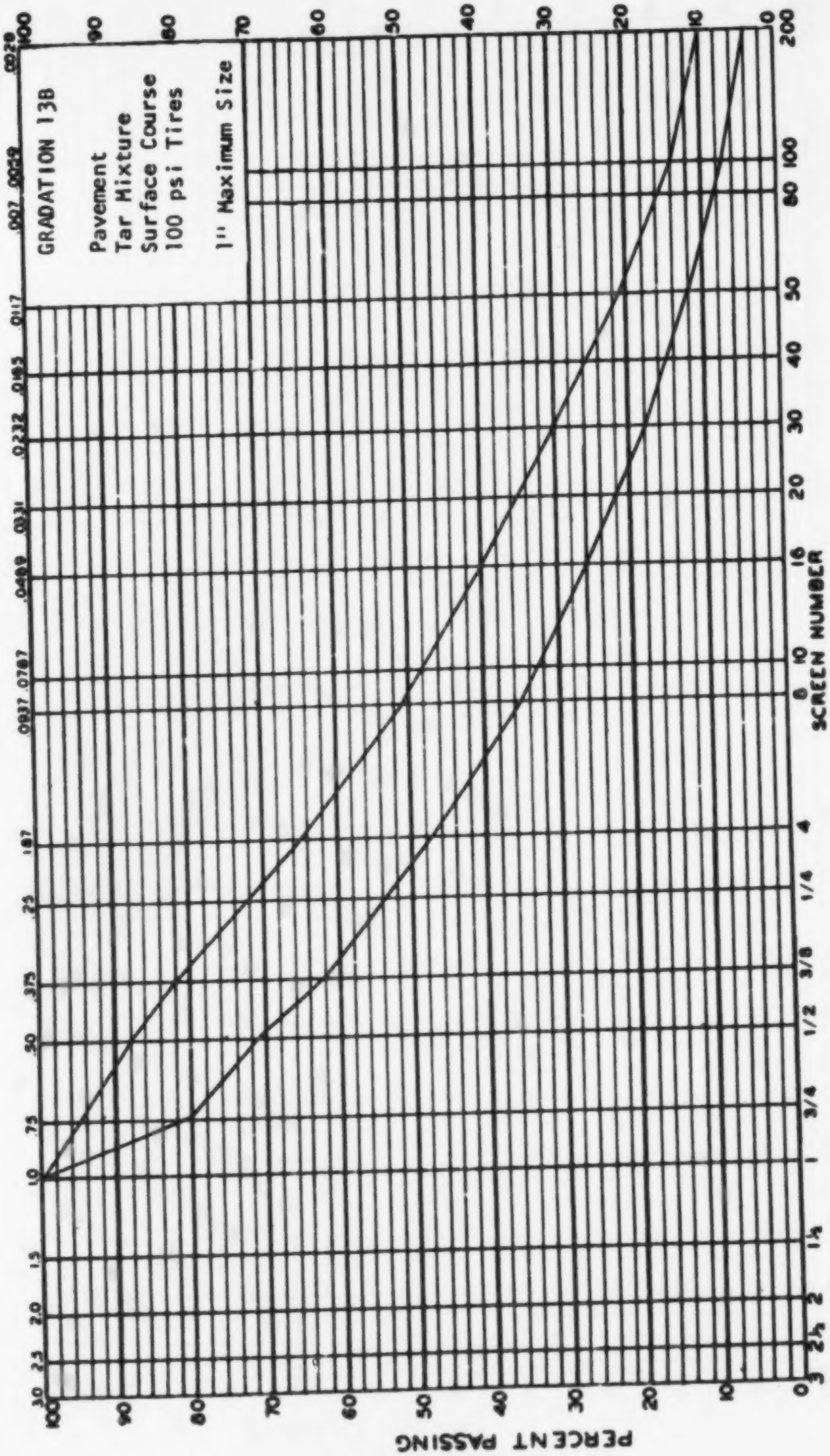


Figure 198. Gradation 13B.

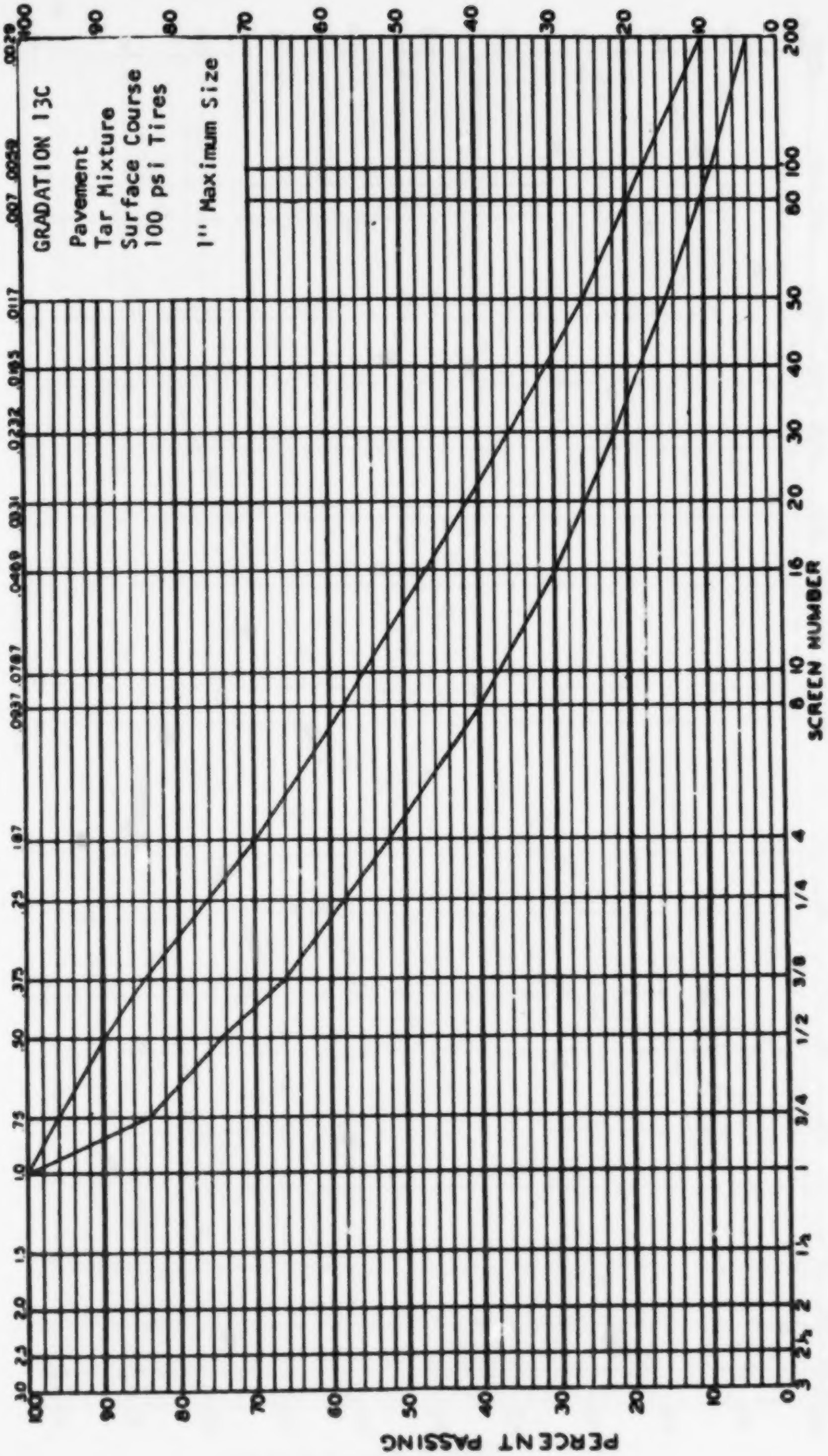


Figure 194. Gradation 13C.

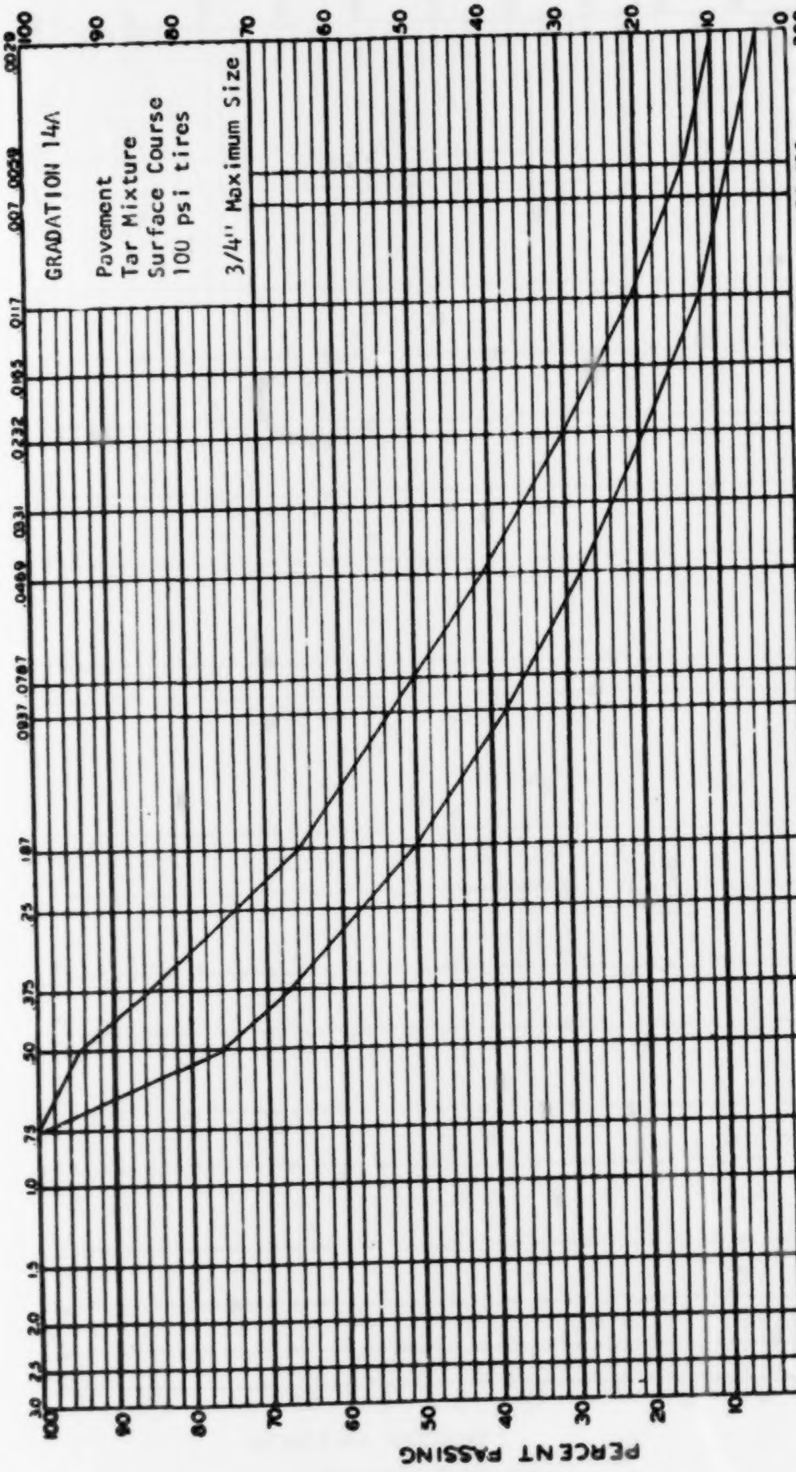


Figure 196. Gradation 14A.

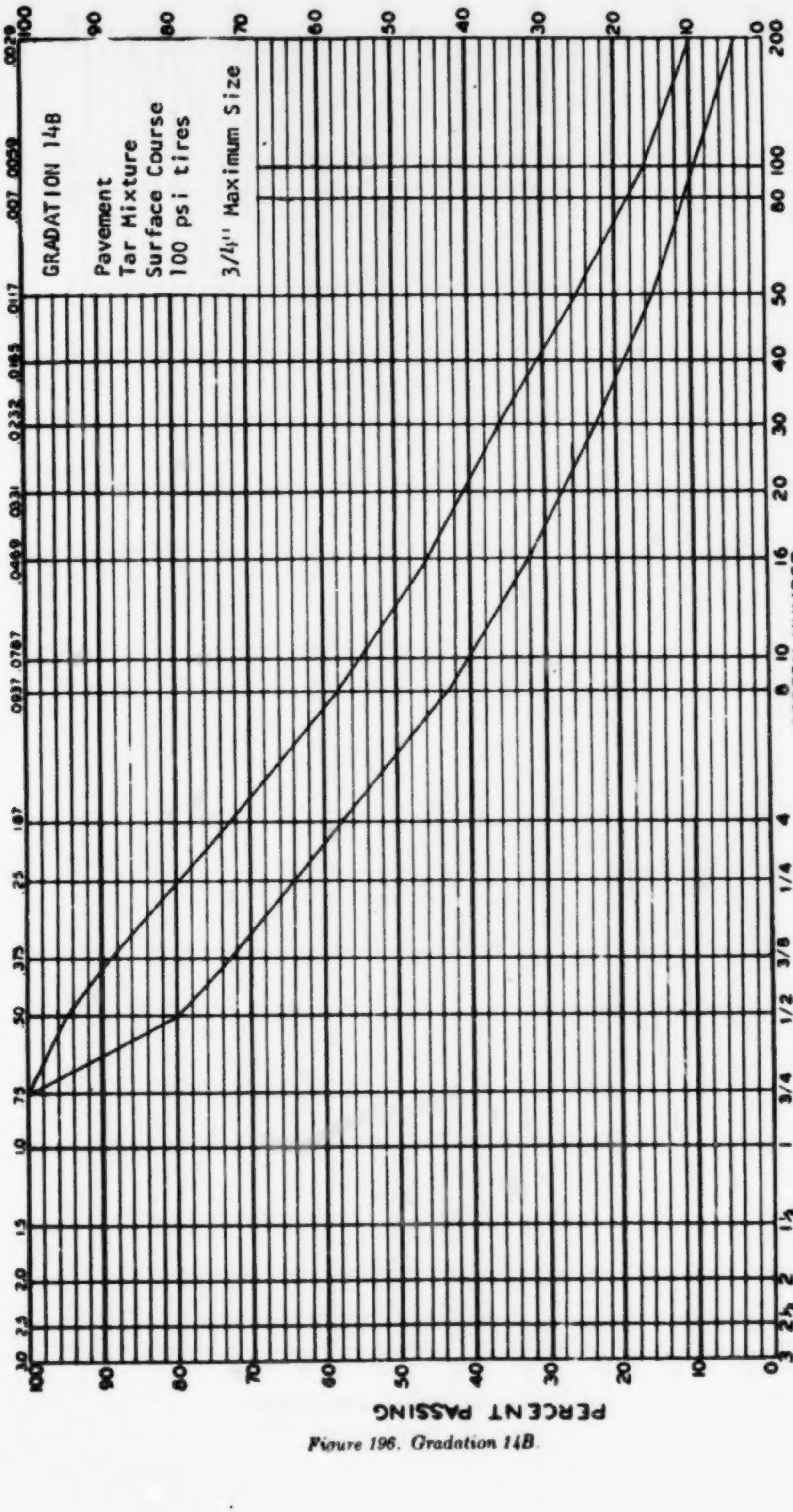


Figure 196. Gradation 14B.

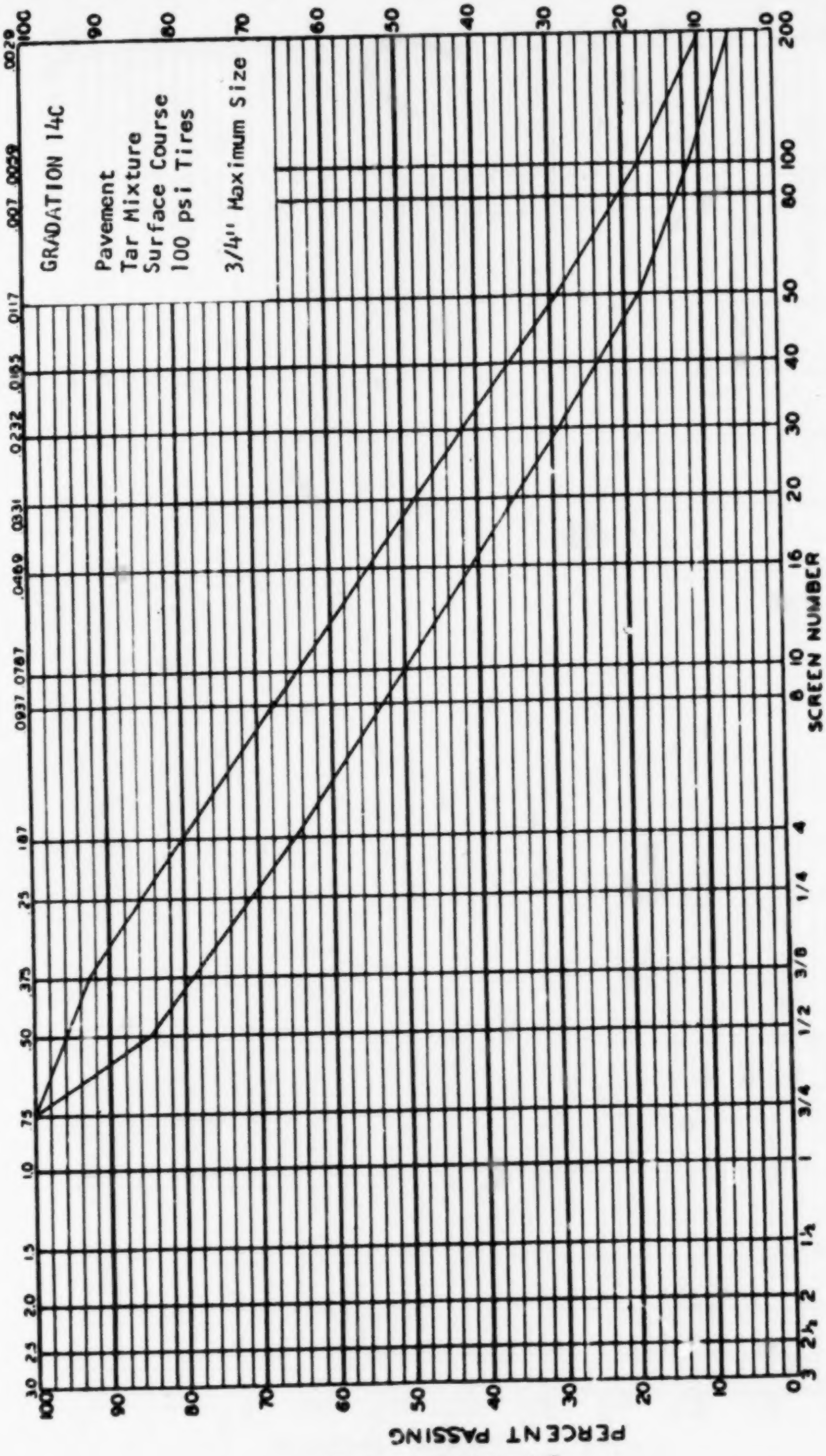


Figure 197. Gradation 14C.

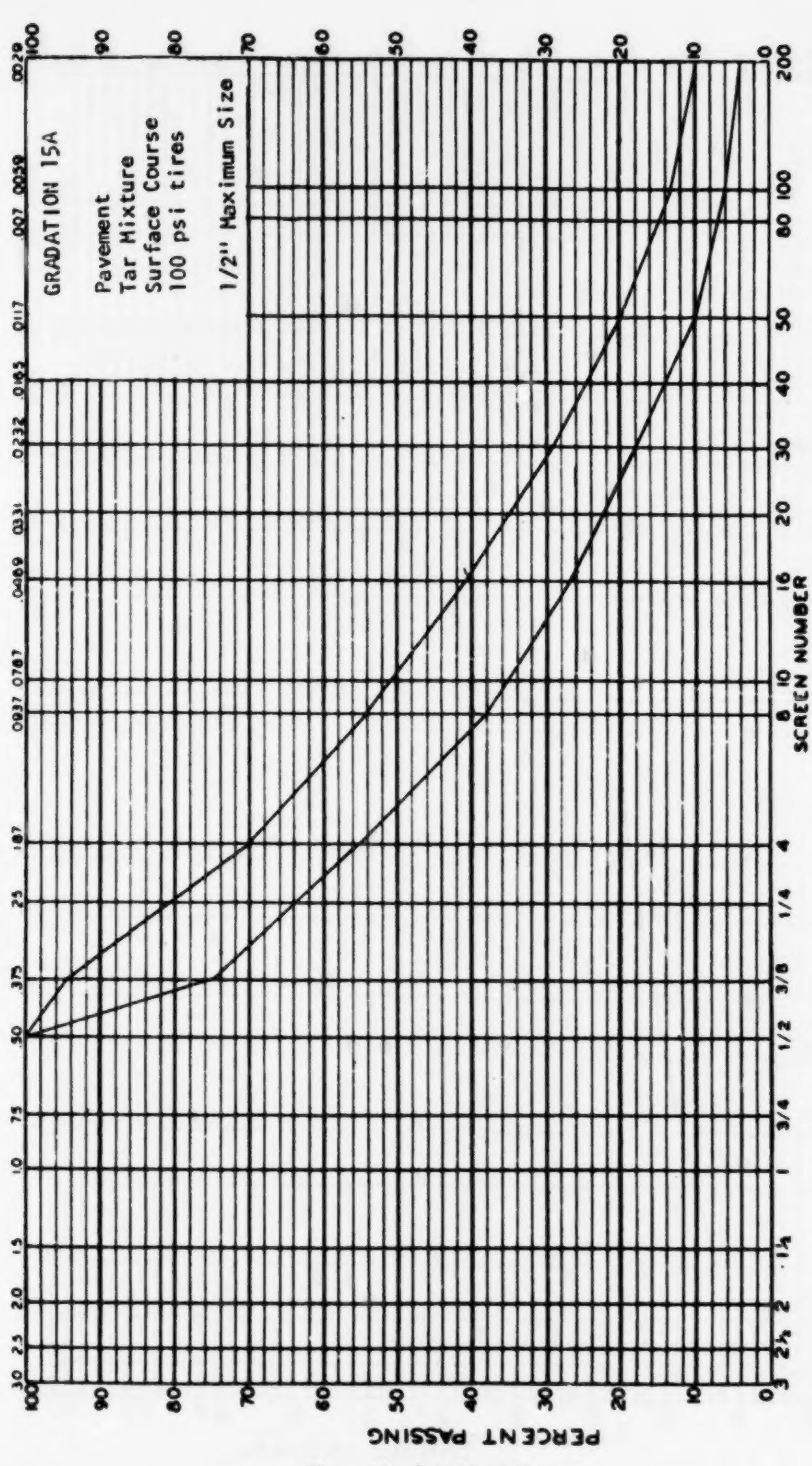


Figure 198. Gradation 15A.

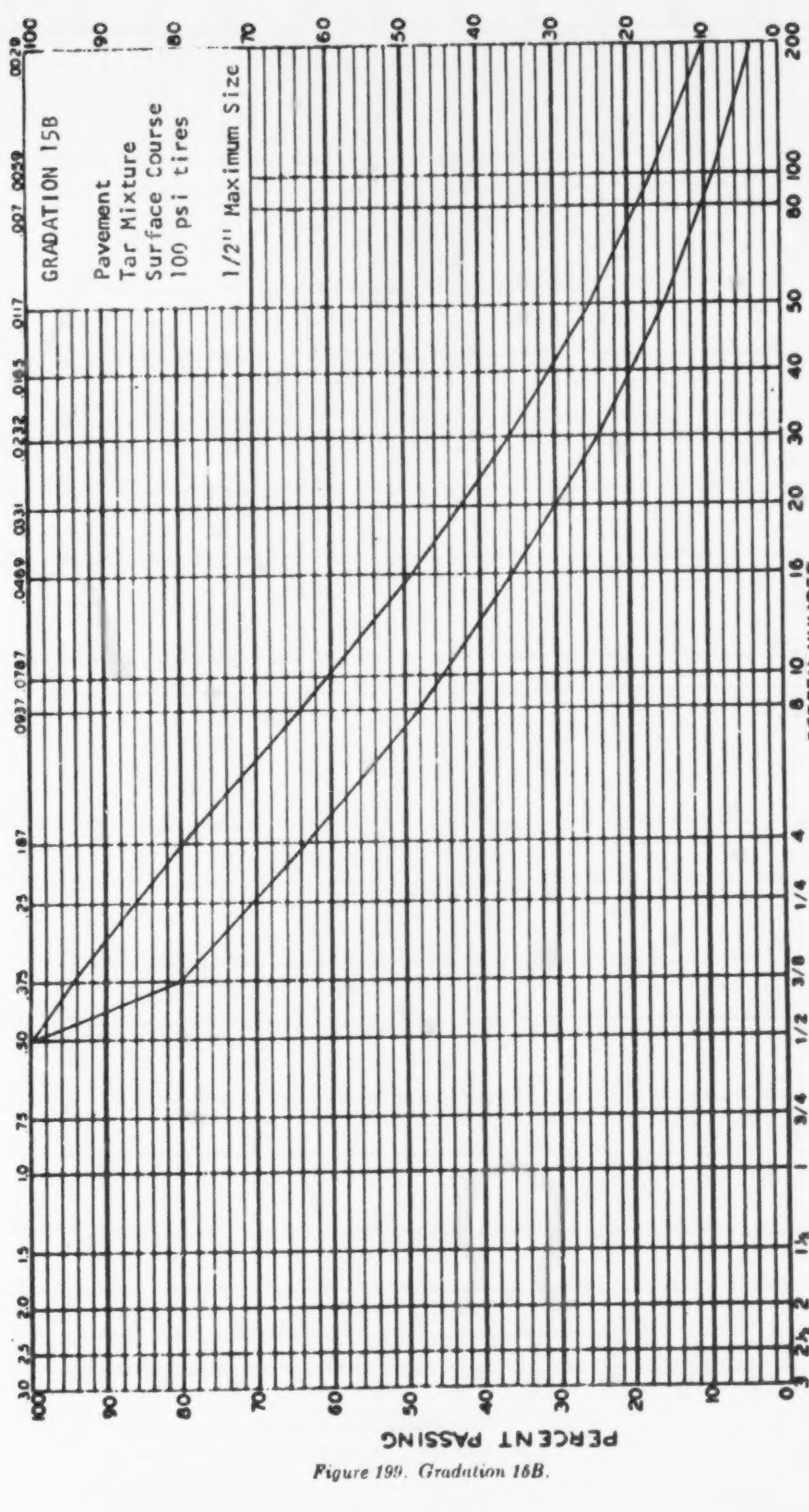


Figure 199. Gradation 15B.

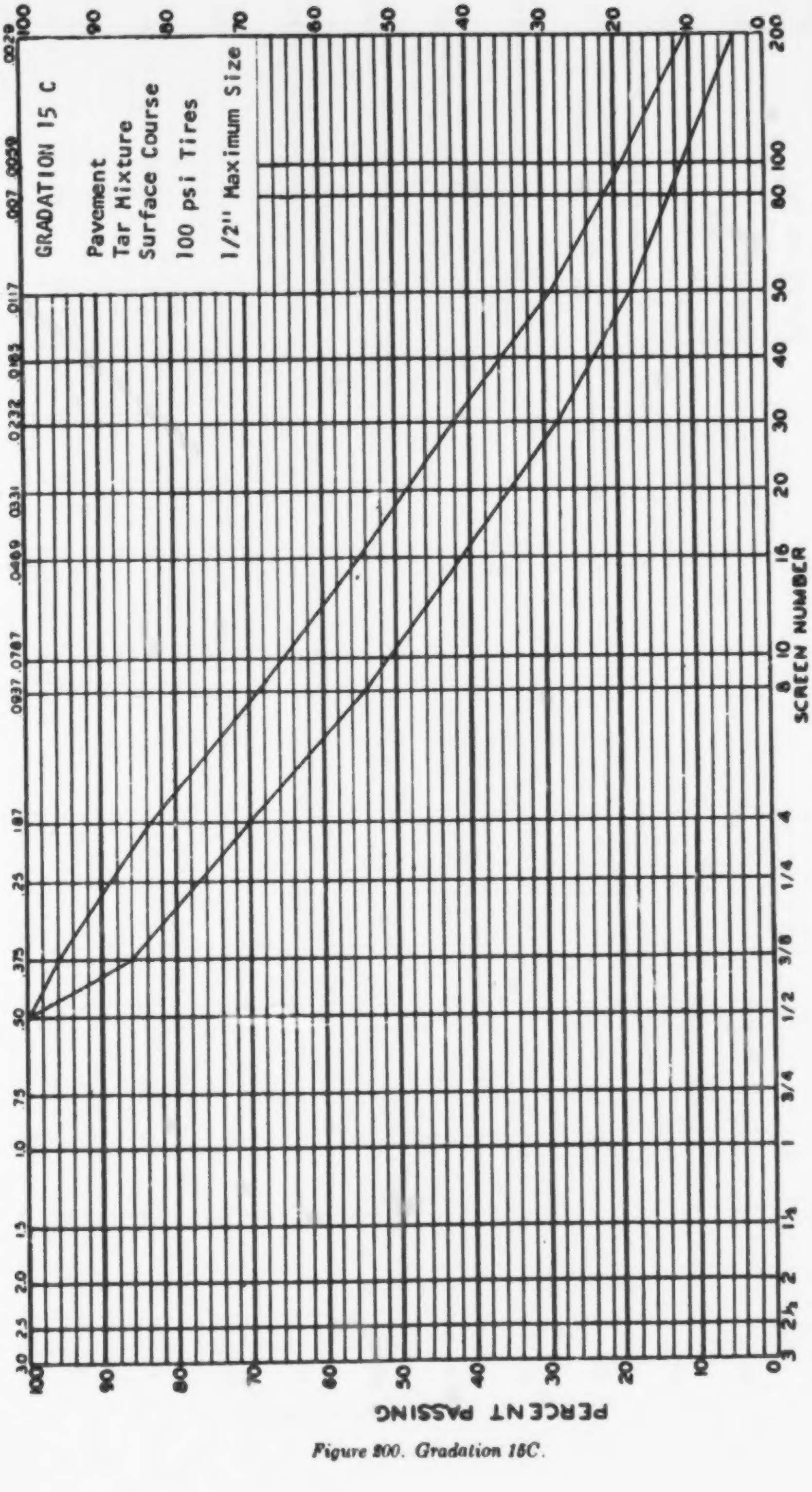


Figure 200. Gradation 15C.

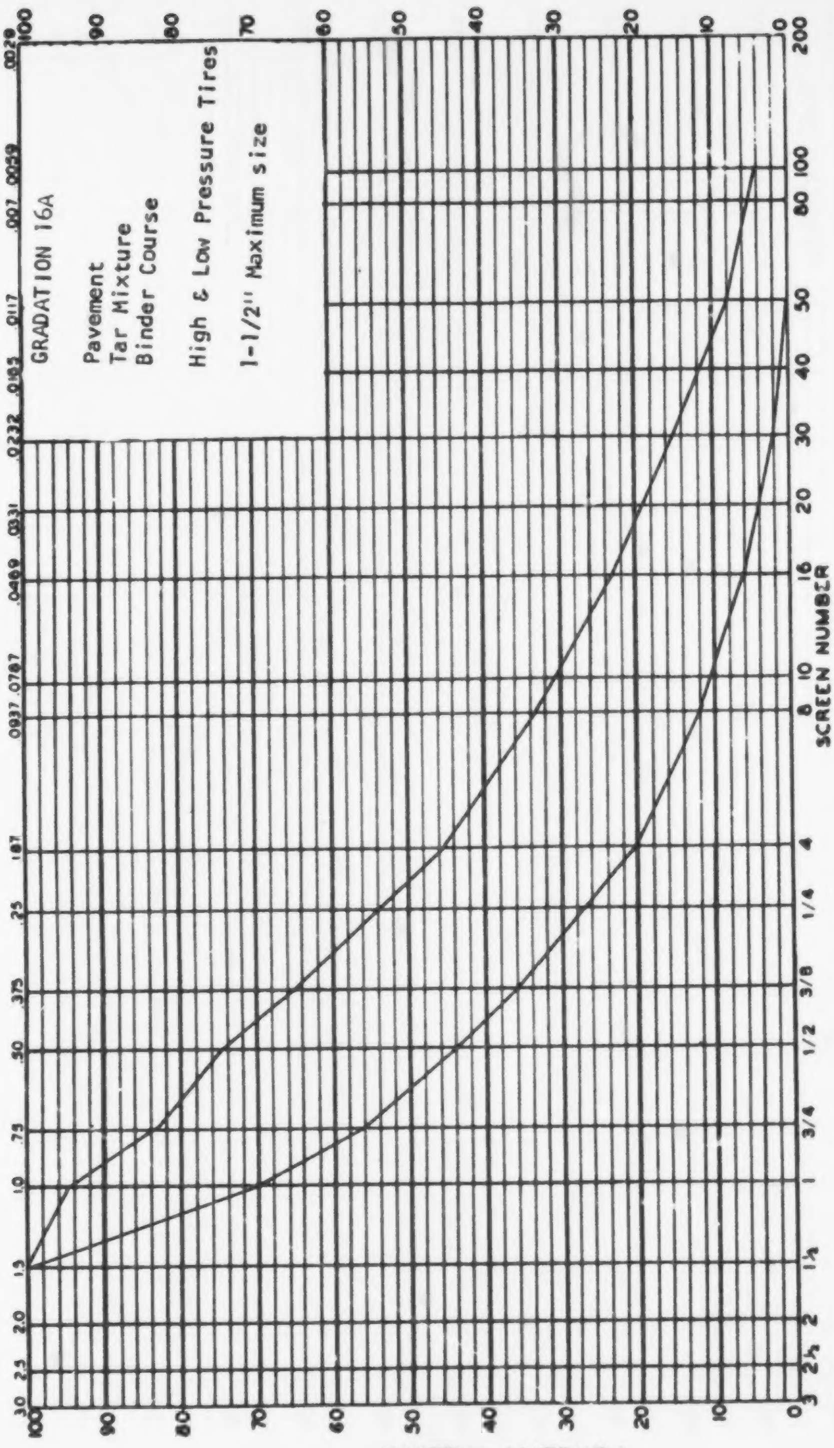


Figure 201. Gradation 16A.

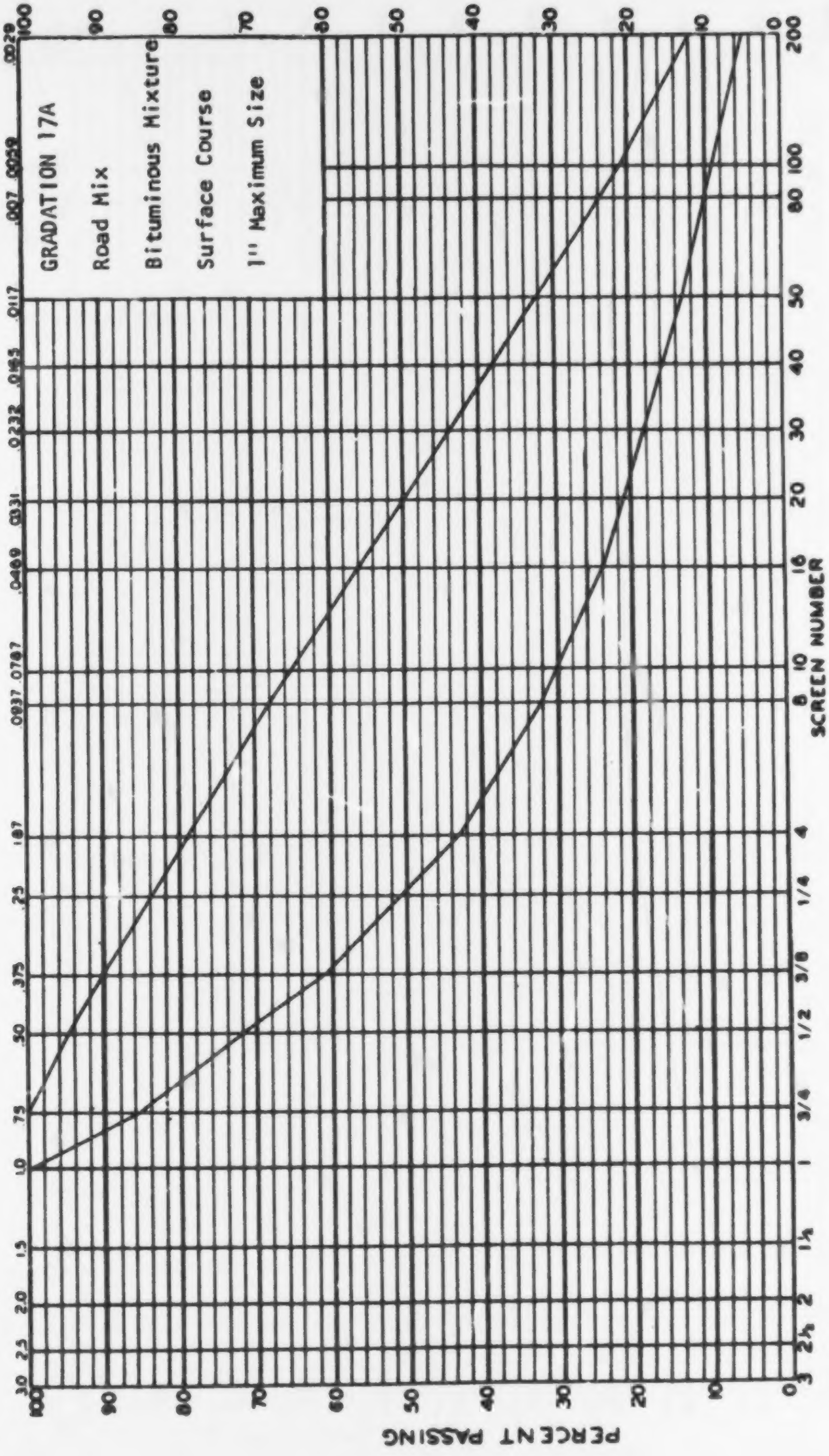


Figure 202. Gradation 17A.

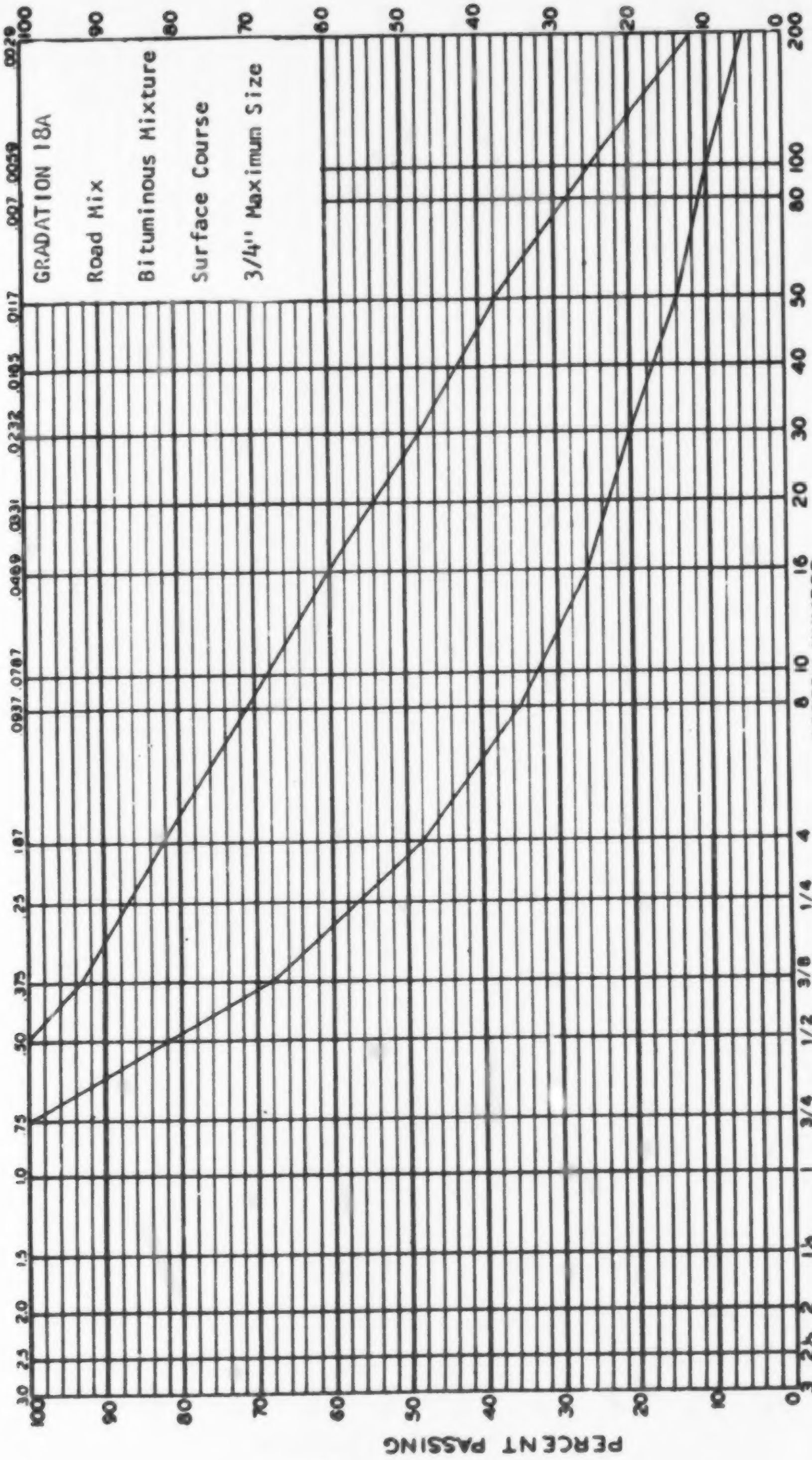


Figure 203. Gradation 18A.

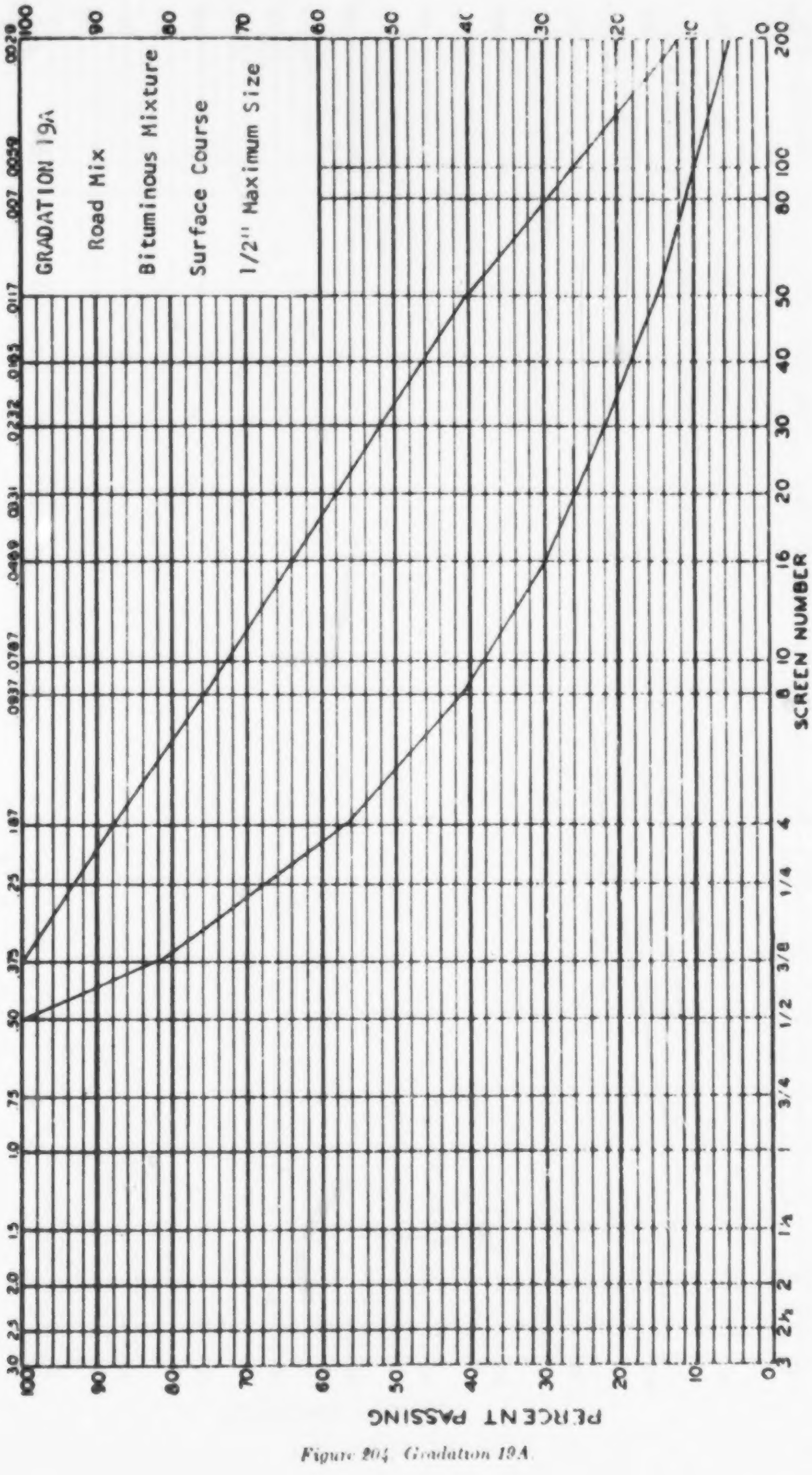


Figure 204. Gradation 19A.

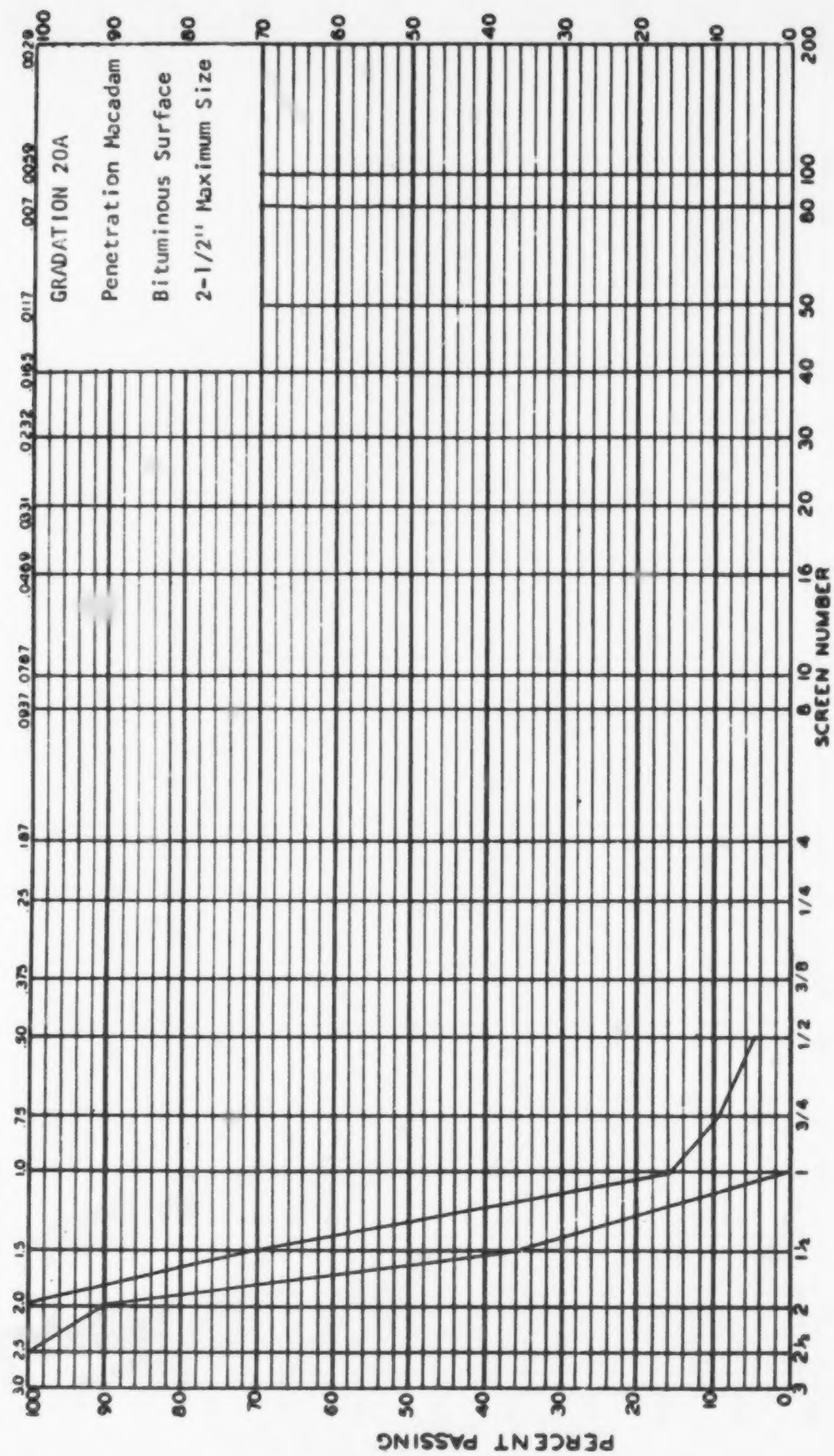


Figure 205. Gradation 20A.

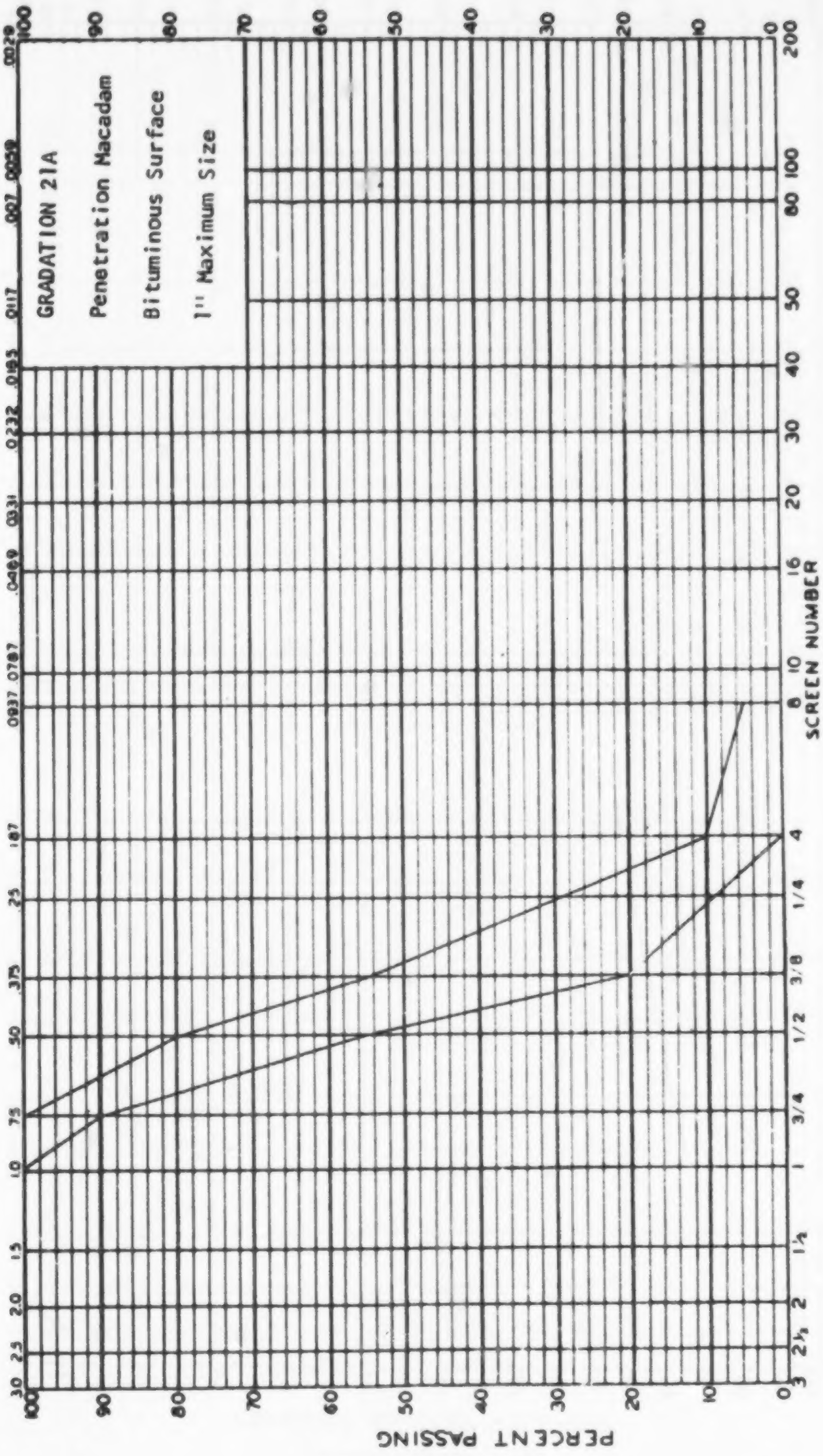


Figure 206. Gradation 21A.

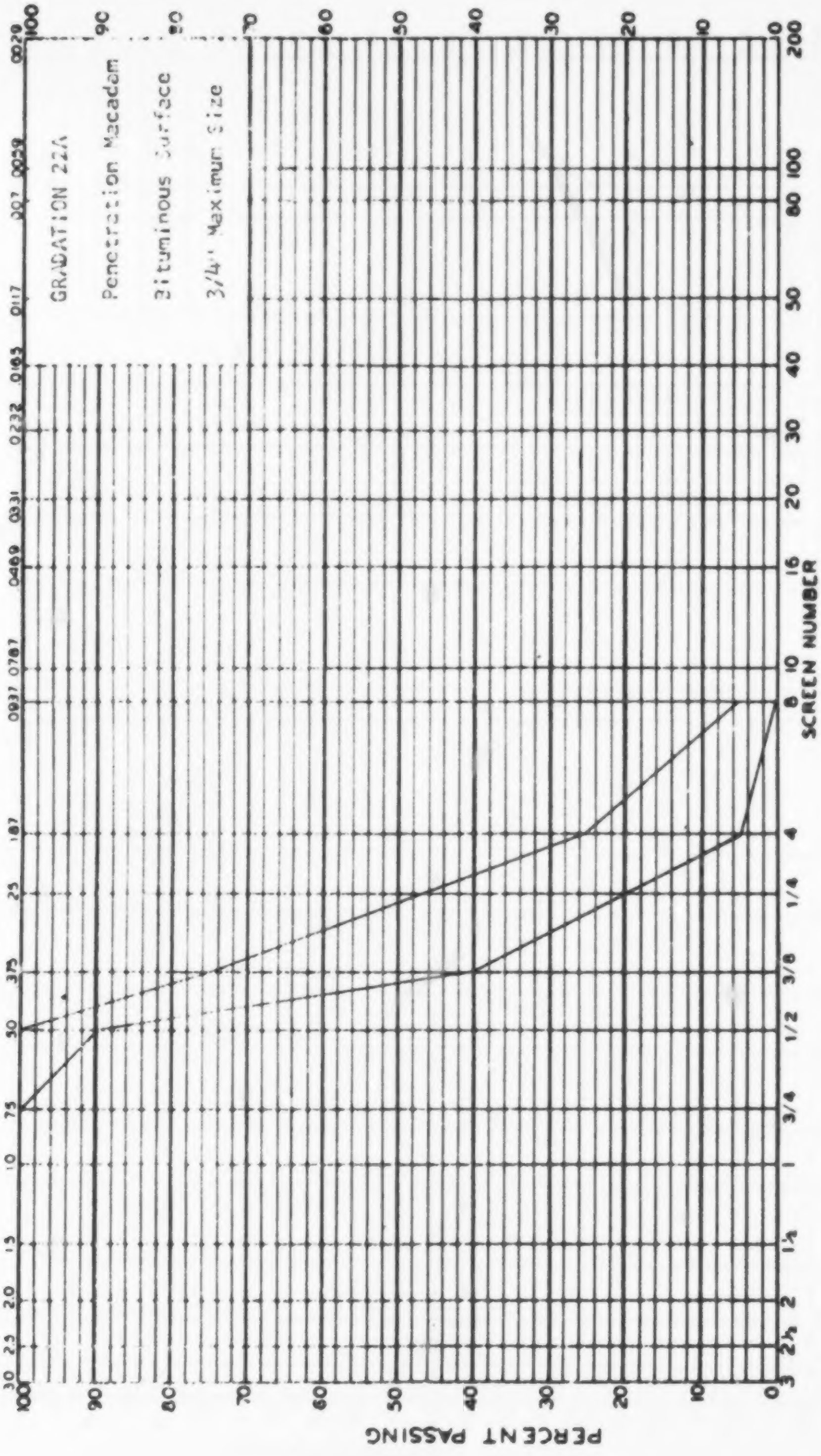


Figure 207. Gradation 22A.

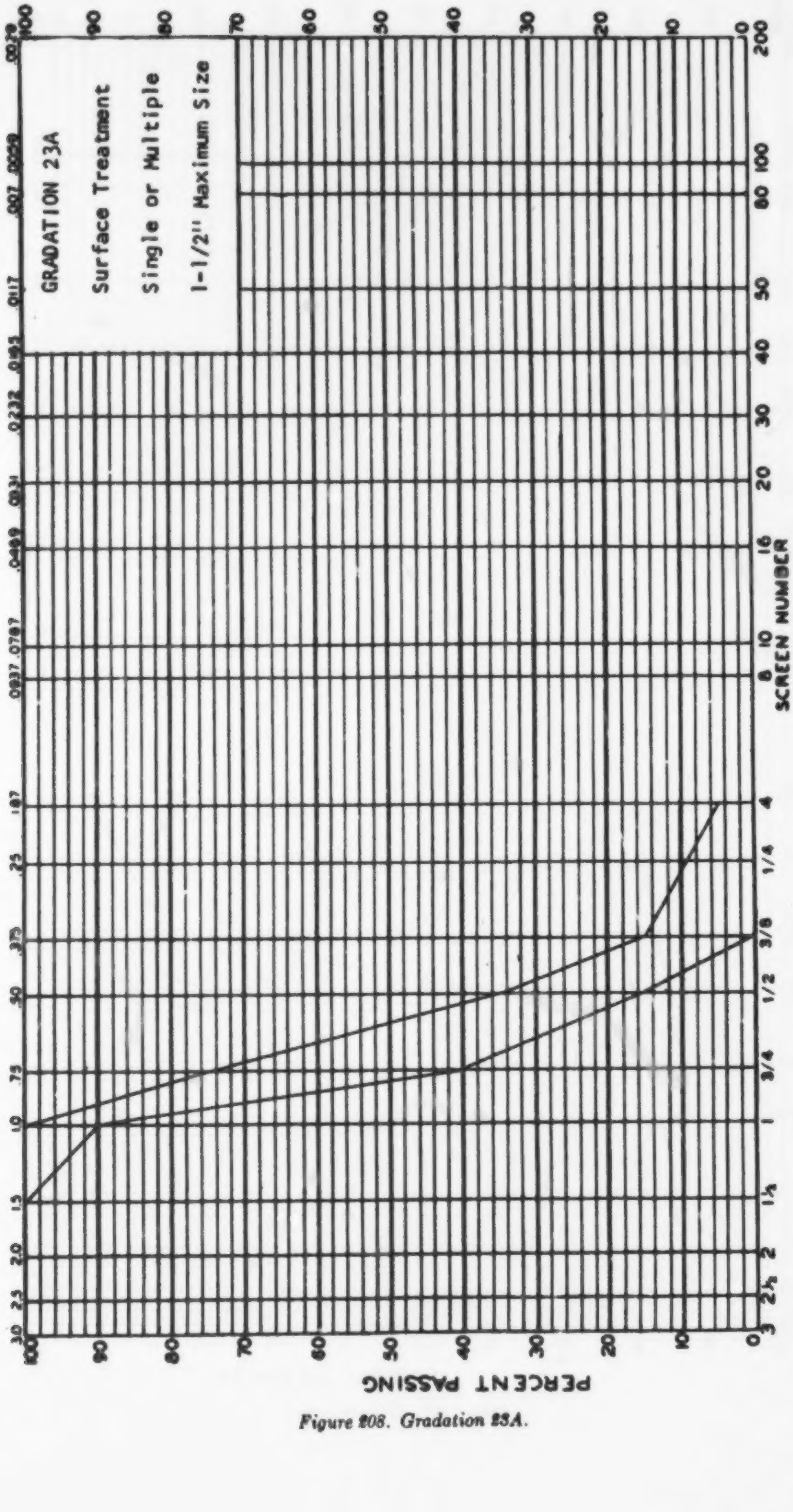


Figure 208. Gradation 23A.

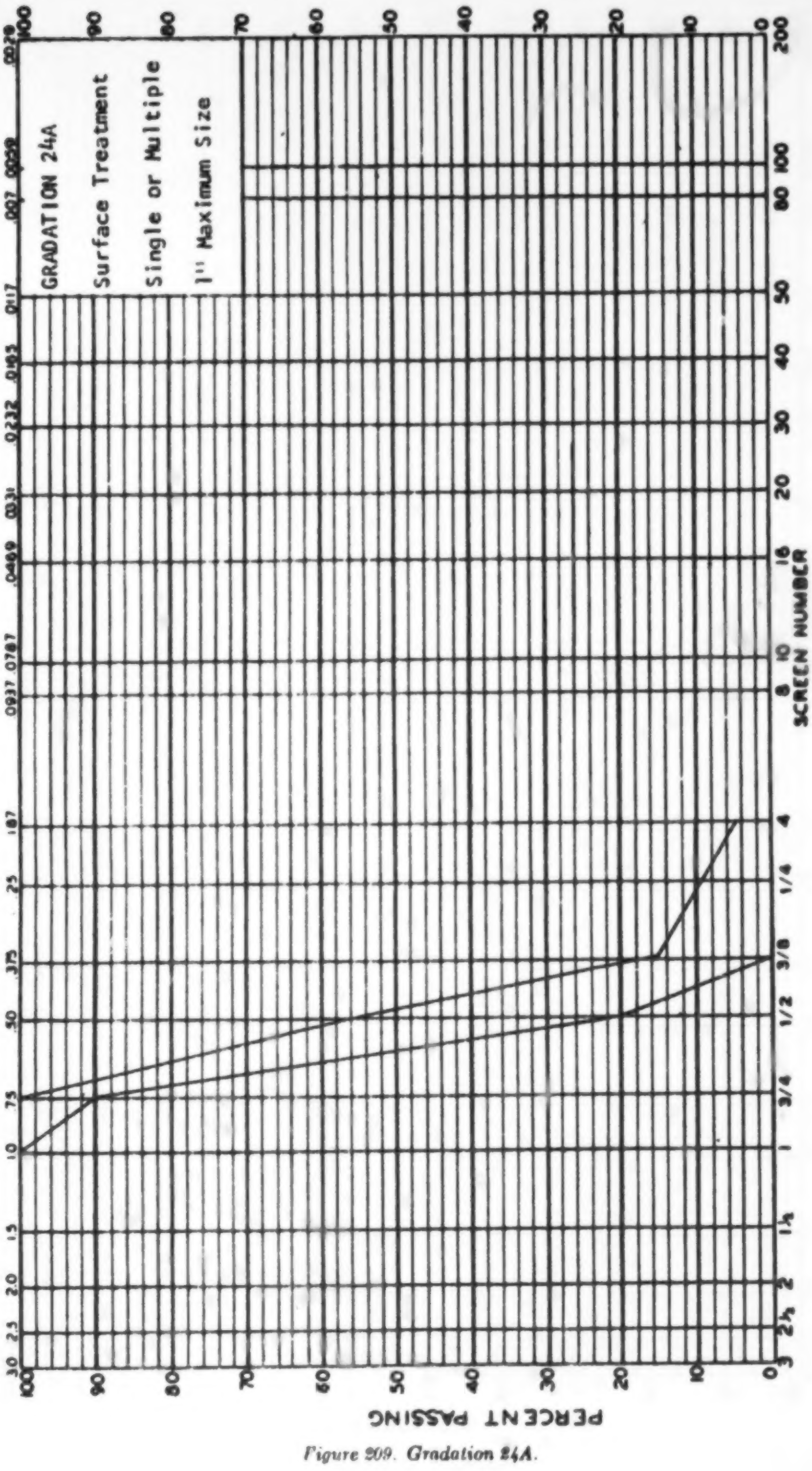


Figure 209. Gradation 24A.

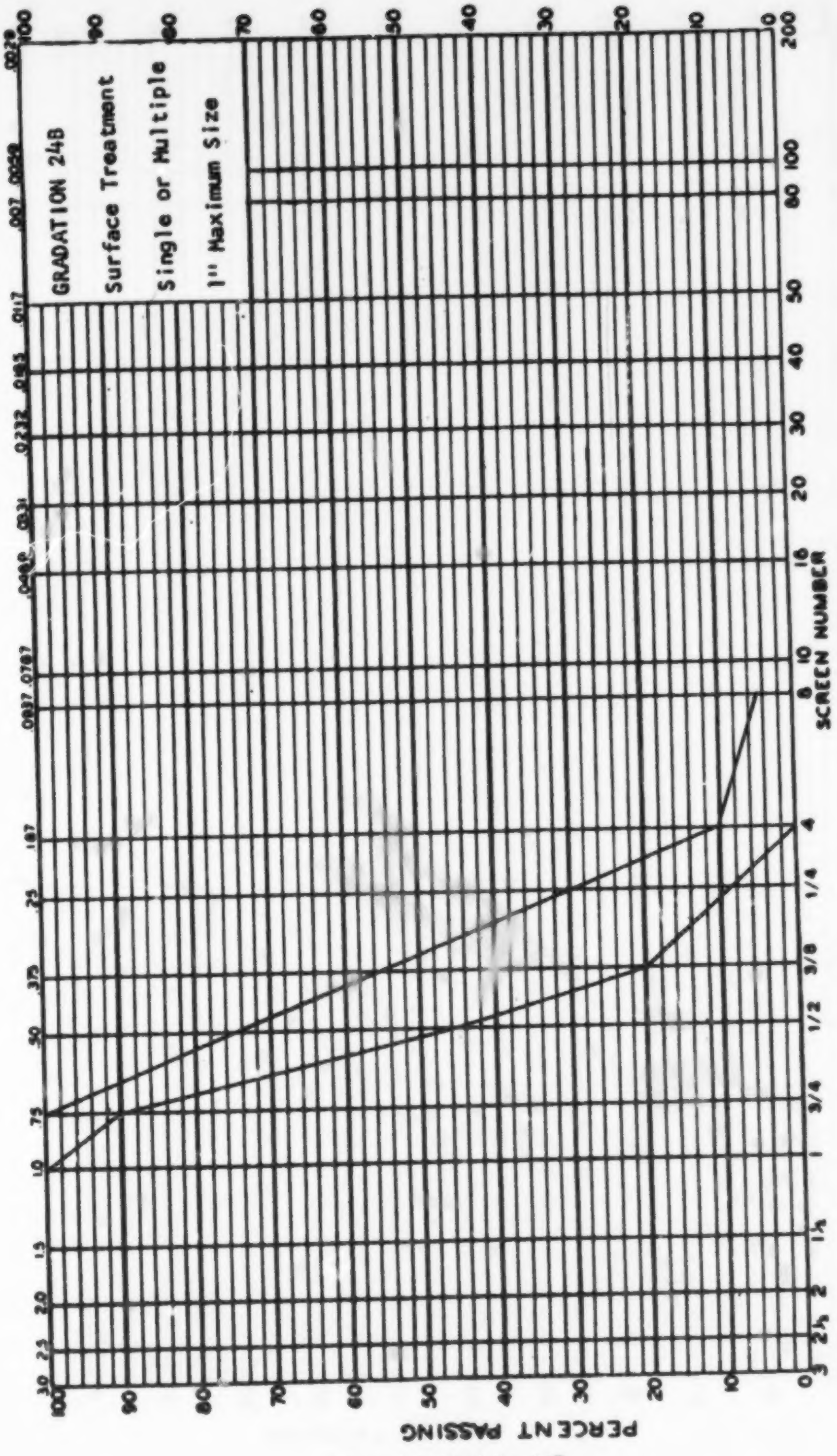


Figure 210. Gradation 24B.

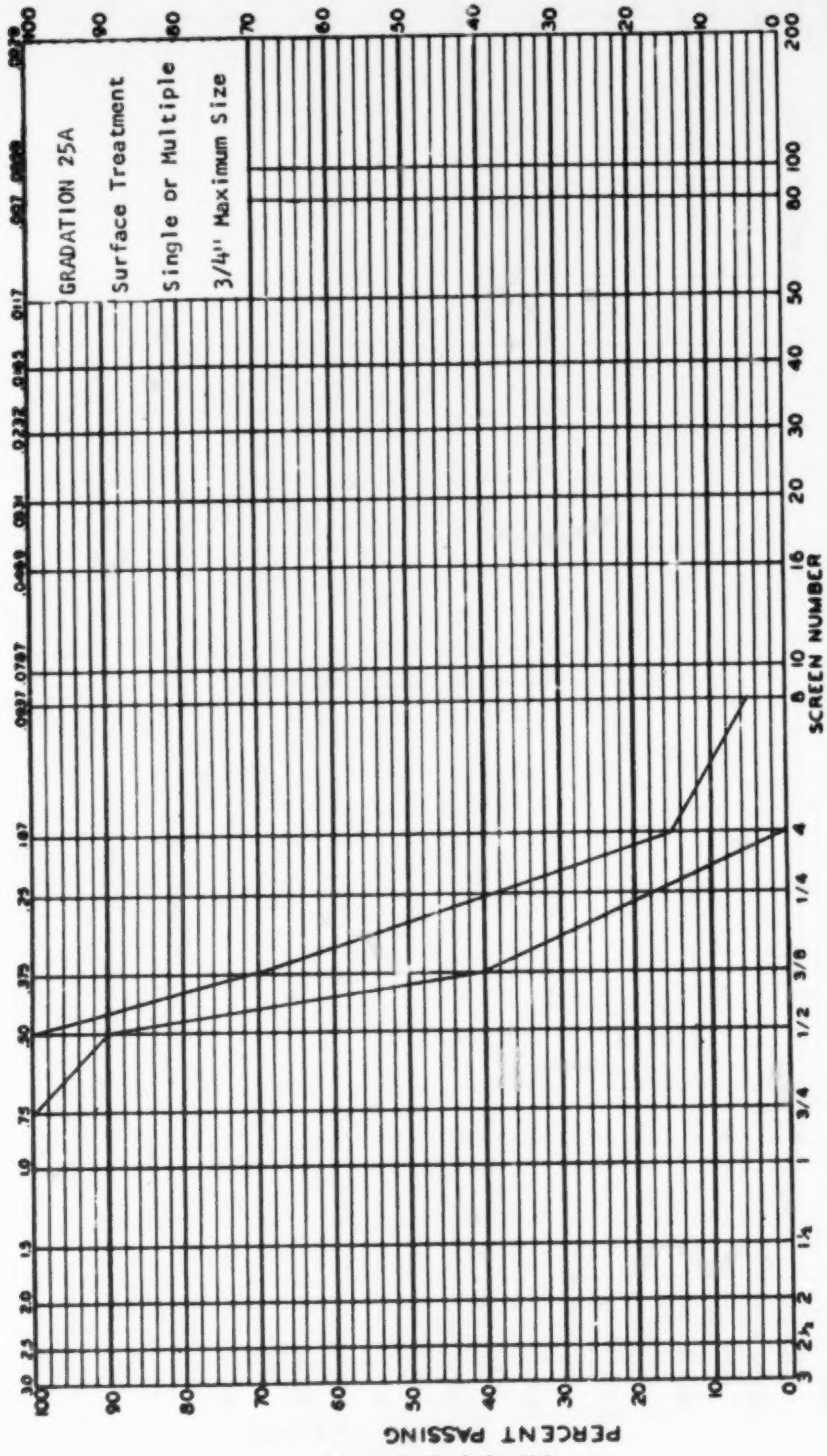


Figure 211. Gradation 25A.

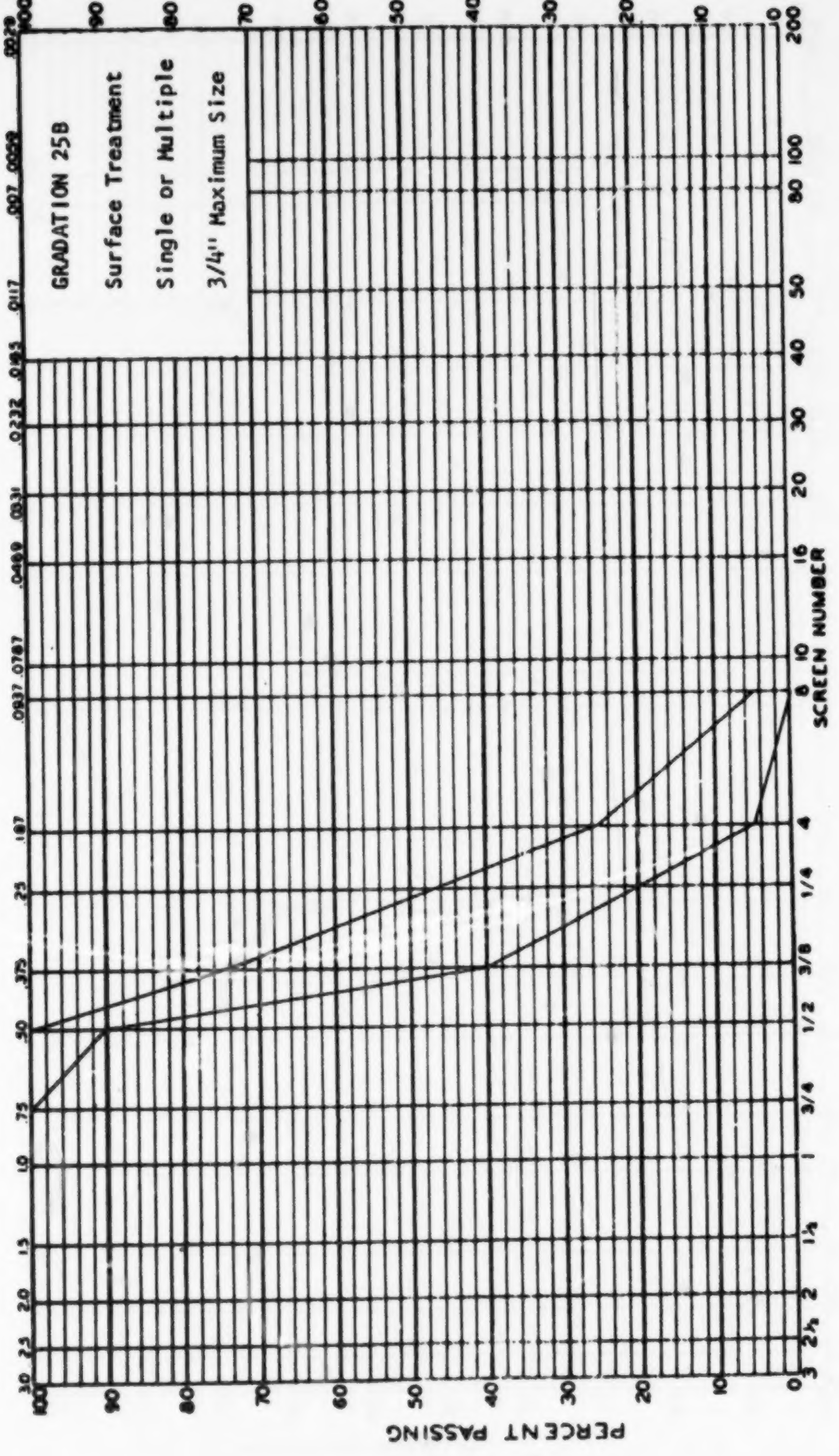


Figure 212. Gradation 25B.

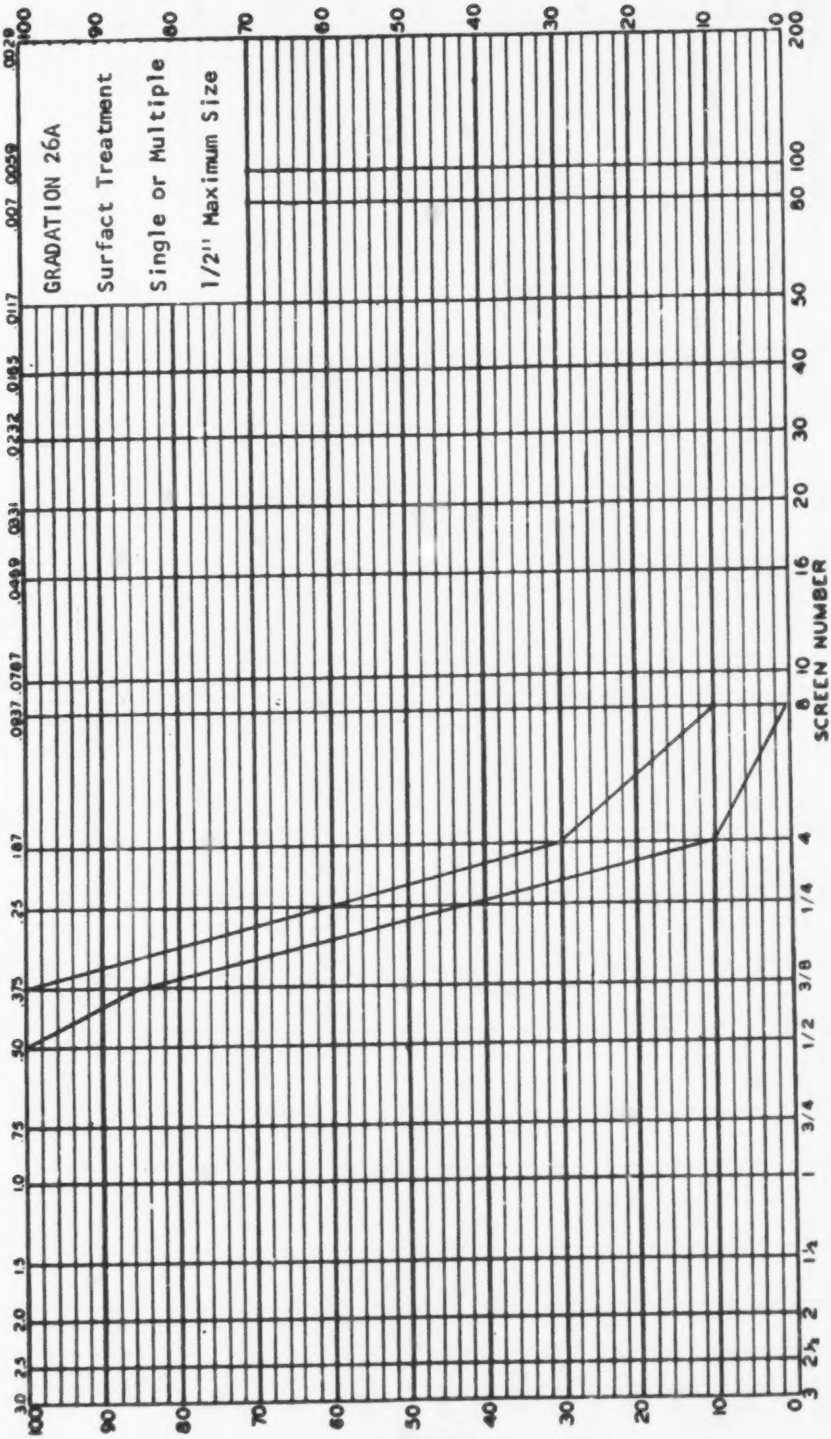


Figure 213. Gradation 26A.

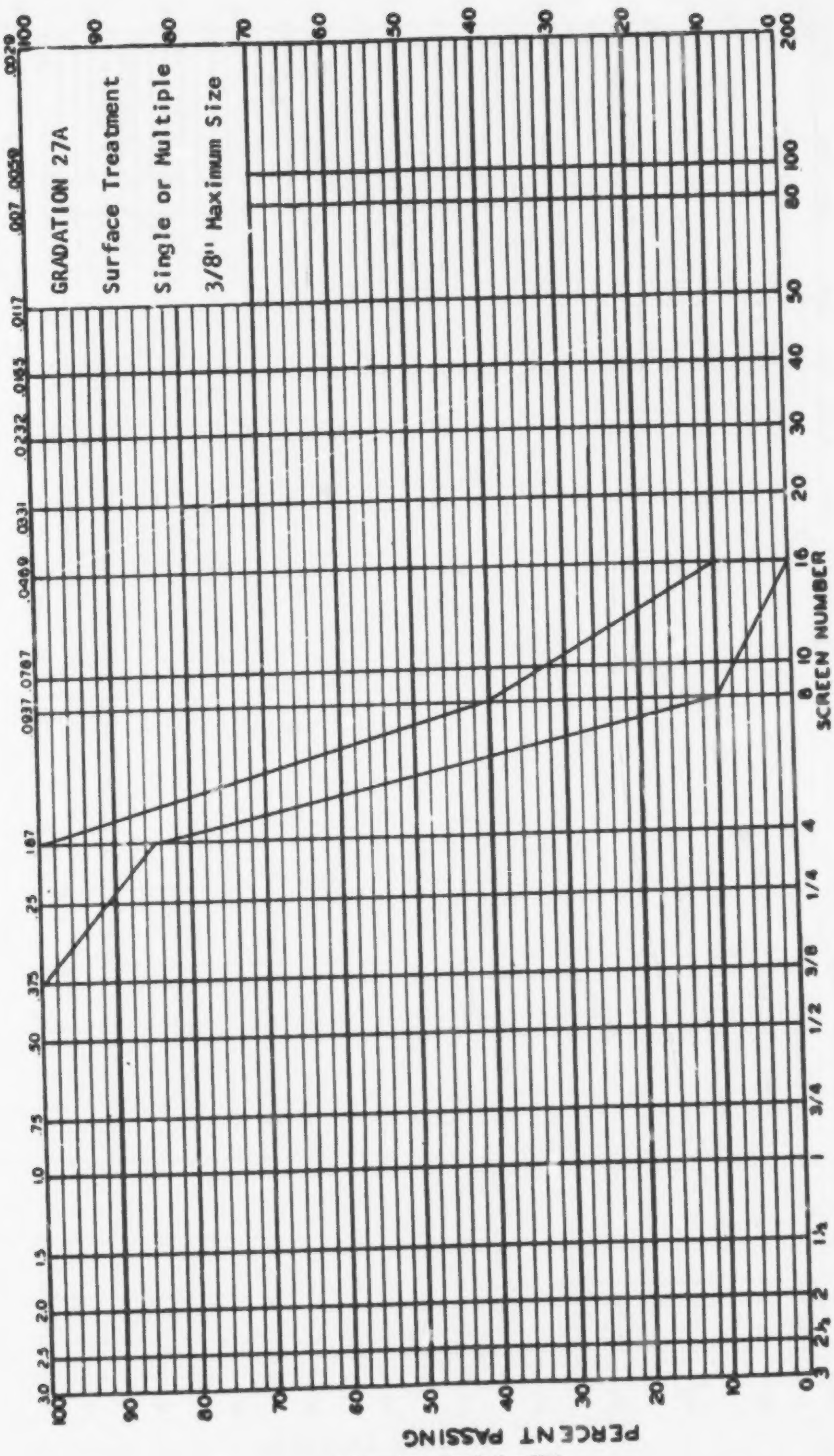


Figure 214. Gradation 27A.

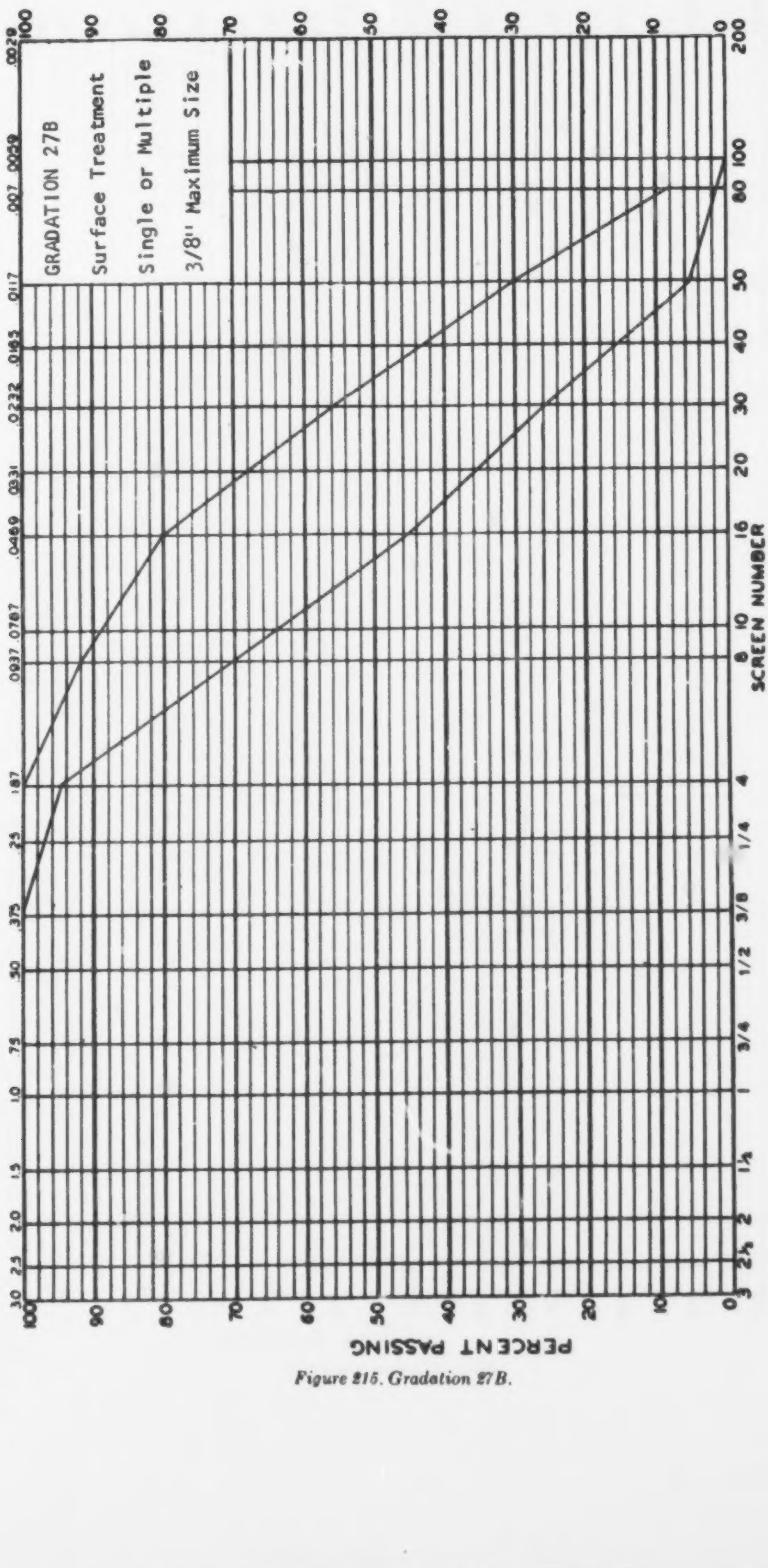
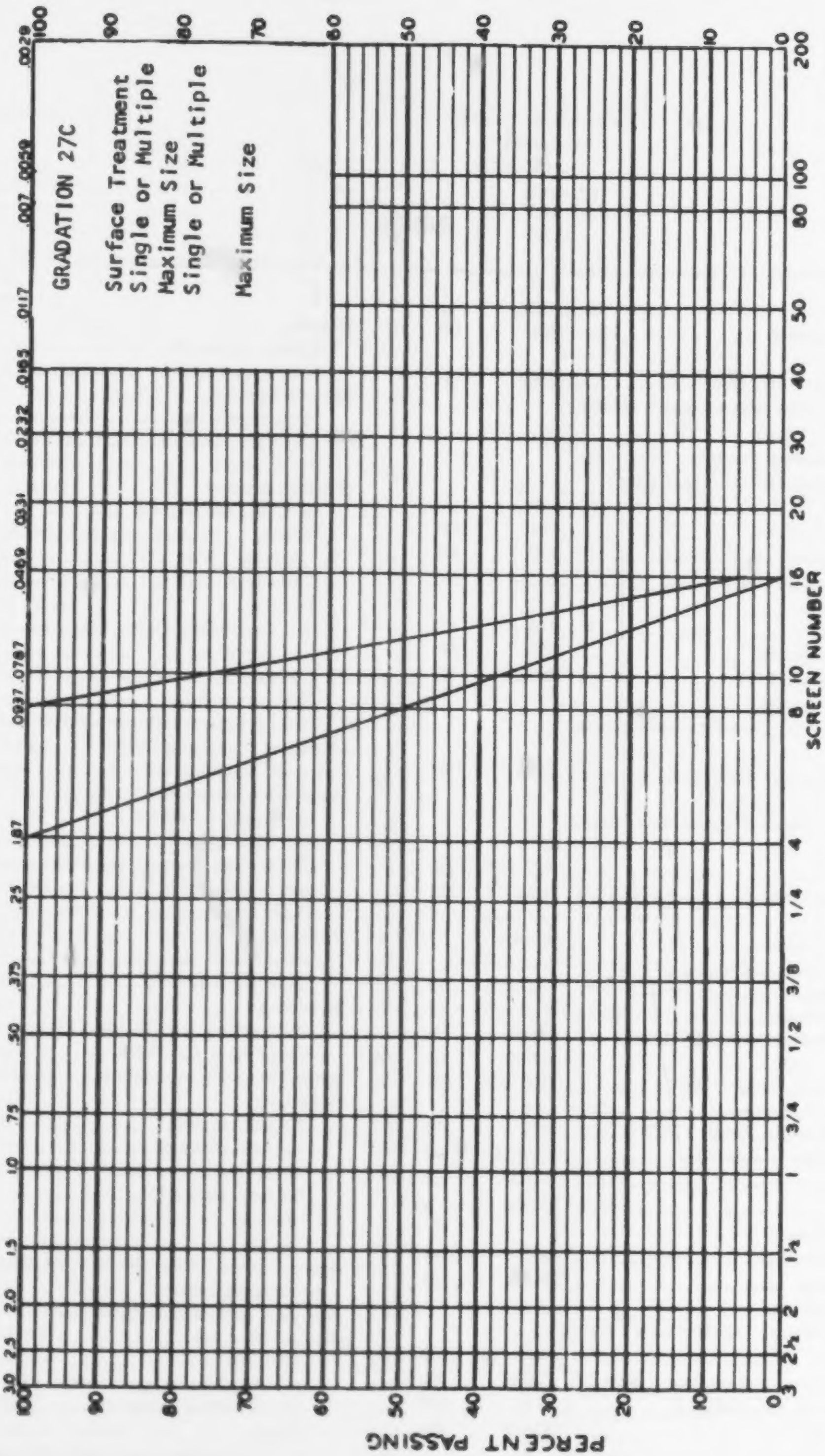


Figure 215. Gradation 27B.



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